COMBUSTION

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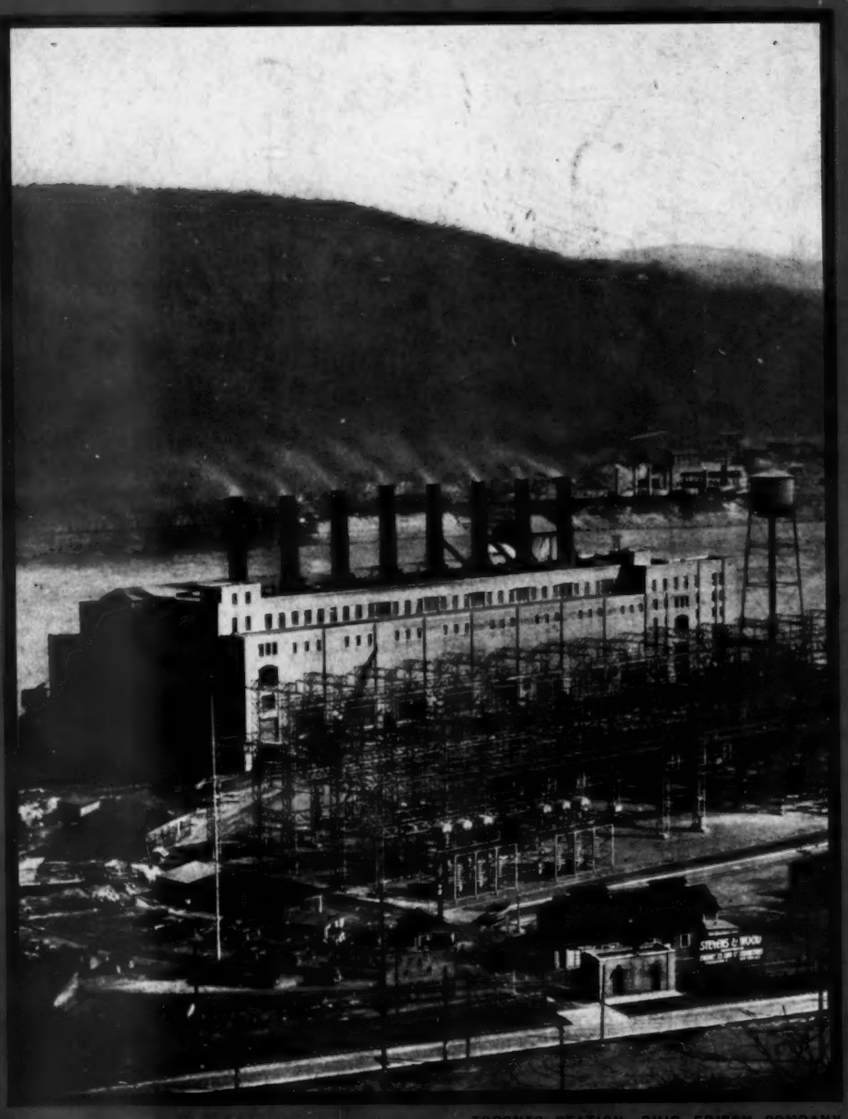


TORONTO STATION, OHIO EDISON COMPANY

Compact Power Units a Feature of New Ford Cargo Ships

By JOSEPH A. MacDONALD

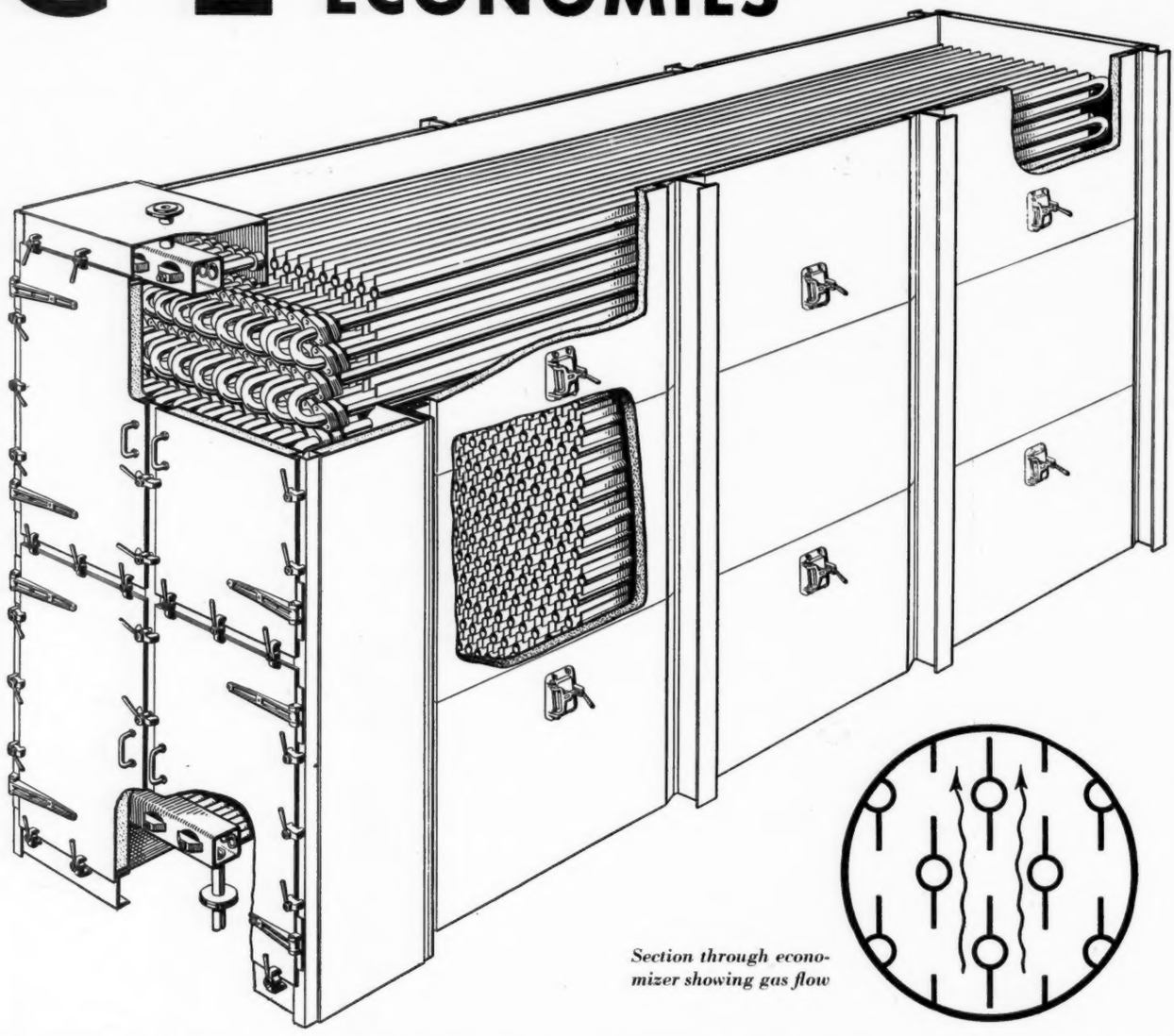
Typical Solid and Liquid Fuels

By WM. L. DeBAUFRE

OTHER ARTICLES IN THIS ISSUE BY

T. A. PEEBLES • OTTO deLORENZI • H. V. SCHIEFER • V. V. VEENSCHOTEN • DAVID BROWNLIE • B. J. CROSS

C-E ECONOMIZERS EFFECT ECONOMIES



Section through economizer showing gas flow

Many dollars' worth of heat is going up the stacks of American power plants every minute of the day. In some cases this heat loss cannot be economically prevented; in other cases the installation of an economizer is amply justified and this waste can then be reduced to a minimum and the plant overall efficiency substantially increased.

The C-E Economizer is an advanced design offering the following important features:

Extended surface in the form of fins integral with the tubes—a construction which assures the maximum sustained heat absorption per lineal foot of tube.

Small overall size for any given capacity—made possible by fin tube design, permitting close nesting and staggered arrangement of tubes.

Minimum pressure loss through tubes—due to return bend design, eliminating headers and header pressure losses.

Minimum draft loss—fins offer but little resistance to gas flow.

Easy to keep clean, thus permitting high sustained efficiency—with vertical fins, there are no soot pockets.

Easy to repair—any tube unit can be replaced without removing any other.

Small space requirement—due to compact design and the fact that all tubes may be withdrawn from one end.

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE **NEW YORK**

COMBUSTION

VOLUME THREE • NUMBER TWO

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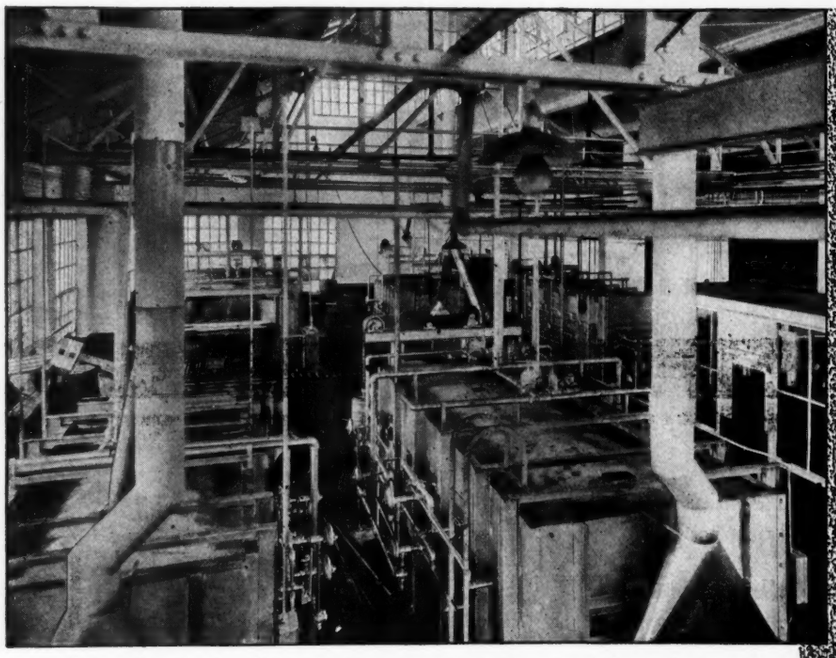
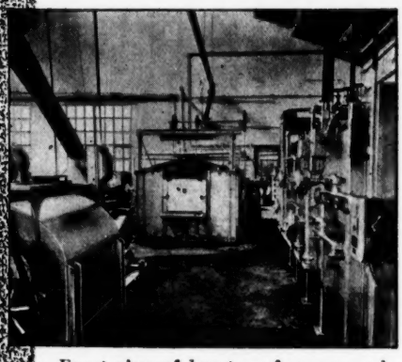
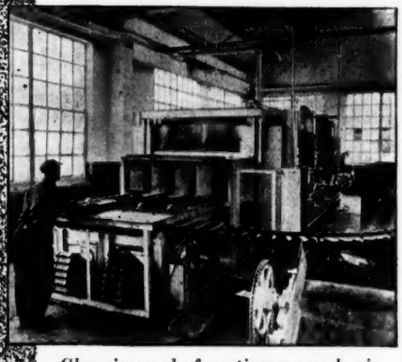
1700° F. in the Furnace— Yet the room is cold!



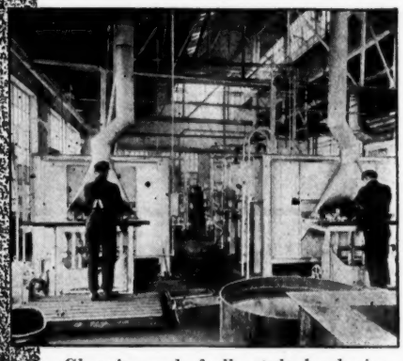
General view of the heat treating room in a large automobile parts factory. Armstrong's Insulating Brick are used to confine the heat to the furnaces.



Front view of box type furnace used for annealing or carburizing.



Charging end of continuous carburizing furnace—insulated with Armstrong's Brick



Charging end of alloy tube hardening furnace in the same plant.

•

High temperatures are kept *inside* the heat treating furnaces by Armstrong's Insulating Brick . . .

VISITORS to the plant of a prominent manufacturer of automobile parts wonder at the comparative coolness of the heat treating rooms. They are still more amazed to learn that a separate heating system is needed to keep sprinkler pipes from freezing in winter! This in spite of temperatures as high as 1700° F. in the furnaces.

There are several furnaces in the heat treating room—furnaces for carburizing and hardening large and small parts. Each unit is insulated with Armstrong's Insulating Brick. Walls are covered with a 9-inch layer, arches with 9 inches, and bottoms with 7½ inches. With this efficient insulation, the room is cold despite the high furnace temperatures.

Fuel consumption is less and working conditions are improved when high temperature furnaces are insulated with Armstrong's or Nonpareil Insulating Brick. The latter is used for temperatures up to 1600° F., Armstrong's to 2500° F., both behind the refractory. There are further savings in the fact that both these brick are machine-sized for ease and accuracy in laying up. See them and test them for yourself—we will gladly send you samples on request. Address Armstrong Cork & Insulation Company, 934 Concord Street, Lancaster, Pennsylvania; Canadian offices in Montreal, Toronto, and Winnipeg.

Armstrong's Ⓐ Product

Armstrong's and Nonpareil Insulating Brick

FOR FURNACES, OVENS, KILNS, AND LEHRS

COMBUSTION

VOLUME 3 AUGUST 1931 NUMBER 2

Smoke Abatement

COL. E. H. WHITLOCK

VISIBLE smoke from a chimney or stack is positive evidence of incomplete or partial combustion. Should combustion be termed combustion when we are visualizing (both optically and mentally) that which is actually and admittedly only partial combustion?

A non-technical definition of the word "smoke" would refer to some shade of gray or black as is most commonly seen in the gas stream being discharged from chimneys or stacks where the color is produced by unconsumed hydrocarbons, as from bituminous coal or oil.

In some cities and localities citizens have become "smoke conscious" to a degree of saturation such that they demand action that will reduce to a minimum or entirely eliminate this visible and obnoxious annoyance.

Engineers have such definite knowledge as to agree that this part of the problem of purifying the air can and should be definitely disposed of. However, since the dissemination of detailed knowledge on a specialized subject such as combustion is very difficult to transmit to all those persons who have responsible charge of work bearing on this subject, the desired goal is slow of attainment.

The accomplishment of this objective is not impossible, nor is it impractical.

The establishment of smoke regulating departments operating under intelligent engineering supervision with established rules and regulations—as is now the procedure in several sections of this country—can do much to regulate the installation of new fuel burning equipment that can readily perform so as to accomplish the desired goal.

The remodeling of present equipment that is not now capable of producing the desired results is a more tedious task and demands excellent sales ability on the part of responsible heads of smoke regulation departments. The sales resistance to the expenditure of capital for remodeling an offensive fuel burning plant can be broken down by the argument of increased efficiency paying handsome dividends on the required outlay.

"Over load" or "peak load" demands on a power plant, such as produce combustion conditions in excess of the capacity of the furnace to deliver the desired total heat release without smoking, indicate that the plant is working beyond its capacity. This condition should not be permitted.

A boiler is one thing and a furnace is another thing, two entirely separate and distinct elements embodying entirely different physical and chemical principles in their requirements and design. The combination of these two has become commonly known as a "boiler plant." Each, however, retains its separate entity. When the capacity of either one is reached, that determines the capacity of the plant and there should be no license permitting the over-demand on either one of the elements to the detriment of human life, health or happiness of the immediate employees or of the citizens in adjacent sections.

Fly ash and sulphur gases present problems entirely different from the smoke problem and each different from the other. The elimination of these two nuisances must soon be seriously considered, and, since they both require engineering knowledge, it is but logical that they will fall under the jurisdiction of the smoke regulation departments.

Control of nuisance by governmental diction must define limits such as are practical of attainment if enforcement of the ordinances is to be hoped for.

The foregoing is intended to imply that these limits are known and hence laws governing smoke abatement work can be enacted and enforced.

Elliott H. Whitlock

Research Professor in charge of Smoke Abatement
Stevens Institute of Technology

EDITORIAL

Correct Boiler Feedwater Conditioning for the Small Plant

CHEMICAL research has contributed generously to American industry. However, improved processes and advanced methods are valuable only in their application and their benefits are directly proportional to the extent of their adoption.

Modern methods of boiler feedwater conditioning have made possible the use of the high pressures, high temperatures and high ratings which characterize modern steam plant practice. If the uncertainty which attended earlier efforts at feedwater conditioning still prevailed, these major developments would not yet have reached the stage of practical application and steam plant practice would be greatly retarded.

Recently a 1400 lb. boiler was taken out of service for its first internal inspection after 18 months on the line. No scale was found, no evidences of pitting or corrosion, no suggestion of embrittlement. That boiler had evaporated over four billion pounds of water in the year and a half of service before its first inspection. Proper feedwater conditioning made that result possible.

In the majority of large plants and in many of the smaller ones, the executives recognize the fact that correct boiler water conditioning is imperative. Their investments must not be jeopardized, life and property must be protected, continuity of operation must be assured, and outage and maintenance costs must be kept at a minimum. Hence, skilled consultants are retained to investigate plant and load conditions, to analyze the available water and recommend the proper method of treatment. Staff chemists make frequent check analyses of both the raw water and the treating process.

These plants no longer have a feedwater problem. They have found the answer and still more important they are applying it.

But what about the little fellow?—the small isolated plant whose engineer switches from one boiler compound to another blindly hoping that some stroke of good fortune will bring relief from the disheartening routine of scaling boilers, and turbining and replacing tubes—ever facing the possibility of a "reduced pressure" ruling or a condemned boiler, for inspection regulations are tightly drawn and the boiler inspectors' rulings are final.

Chemical research has made possible the rapid advancement in steam plant practice, but the full benefits of that research will not be realized until the advantages of correct boiler feedwater conditioning are made readily available to the small plant—the plant that needs help the most, because it is the least able to help itself.

Fair Prices—The First Requiste To Business Recovery

AT the recent meeting of the 18th National Foreign Trade Convention in New York a final declaration was issued in which a single factor was selected as the most serious deterrent to business recovery,—i.e., profitless selling. The sense of this declaration is summed up in the following abstracts.

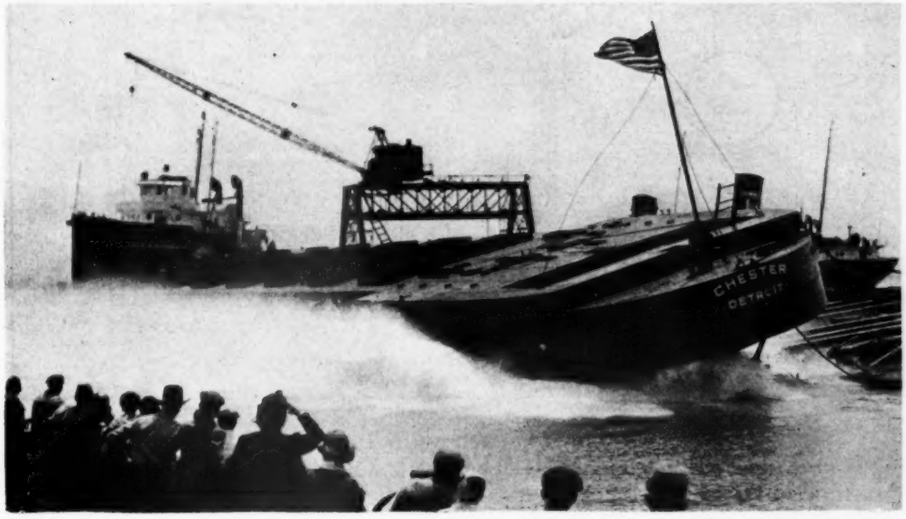
> "The most significant fact in the status of the international trade of the world is that the volume of merchandise sales about equals that of a few years ago when business was enjoying substantial prosperity. But price levels have fallen to the point where profit has been largely eliminated. The chief factor of the present situation is profitless merchandizing.
>
> "An essential necessity of the present economic situation is an advance in commodity prices. When prices are falling buyers tend to withdraw from the market. It is rising prices that stimulate buying and consumption and a return of prosperous times. Anything, therefore, which tends to postpone recovery in commodity prices, more especially those influences which are unfair and uneconomic in character, should be discountenanced.
>
> "Competition is unfair both to industry and to the community when price cutting compels the sale of goods at a loss. Basic commodities are being sold at cost or less. Profitless merchandising retards prosperity, and affects the position of the wage earner."

During the nine sessions of the Convention, leading authorities discussed every phase and factor of the present situation, and it was the consensus that this declaration emphasized the point of greatest and most immediate importance.

The effort to establish prices that assure a fair profit should be pursued vigorously in every line of business. This keynote was sounded by James M. Farrell of the U. S. Steel Corporation in his recent remarks before the Steel Institute, and was forcibly reasserted at the time by leading economists and industrial executives.

Until all major industries are selling their output at a price that insures a fair profit, there can be no return to normalcy, not to mention prosperity. It is particularly important for the buyer who takes advantage of present competition to the extent of making his purchases at profitless prices to realize this fact as by following such a policy he is contributing to delay in business recovery and thus in the long run is injuring his own business.

Compact Power Units a Feature of New Ford Cargo Ships



Launching of new Ford Cargo Ship, Chester.

By JOSEPH A. MacDONALD
President, Henry J. Gielow, Inc.

The two Ford cargo ships described in this article are the first of their type to be built and are characterized by many novel features. Of particular interest is the marked economy of space which is evidenced by the fact that the two 800 hp. power units installed in each ship, consisting of oil-fired boilers and steam turbines, occupy but 30 ft. of the ship lengthwise. The free space available for cargo is 145,000 cu. ft. These ships will be used between the River Rouge plant and Edgewater, N. J. They can also be used for coastal service.

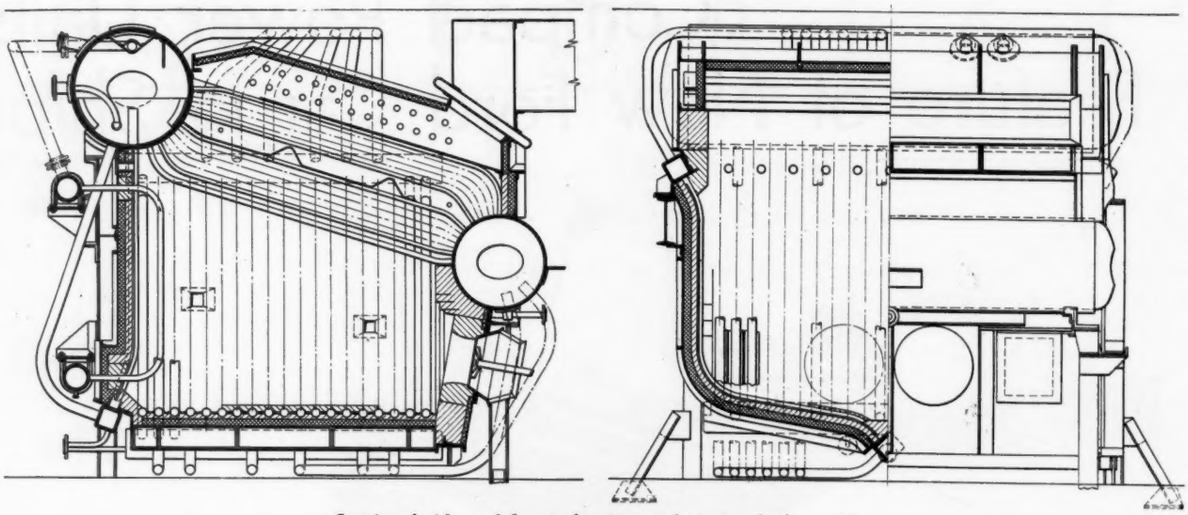
THE two 300-foot cargo ships, built for the Ford Motor Company by the Great Lakes Engineering Works of River Rouge, Mich., have been launched and will be ready for service within a few weeks, which, in itself, constitutes something of a record in shipbuilding. Slightly more than five months after contracts had been signed, the ships had made their trial trips and were ready for operation.

The vessels, named the Chester and the Edgewater, are identical in every respect. Designed by Henry J. Gielow, Inc., naval architects, the ships are full New York State Barge Canal size, 300 feet in overall length, 43 feet in beam, 20 feet in depth and with drafts of 9½ feet when loaded with their normal cargoes of 1800 tons. Because they will be used between the Ford plants at River Rouge and Edgewater, N. J., it was necessary for the architects and the builders to reduce the maximum clearances to 15 feet by means of housed masts, submerging pilot houses and collapsible stacks.

It was fundamental that the ships should be so designed that the highest economical speed might be accomplished at the lowest cost per ton mile. This was achieved through the use of exceedingly compact Westinghouse 800-horsepower geared turbine power plants, two in each boat, with oil burning boilers of the marine water tube, water wall type built by Combustion Engineering Corporation. The boilers are designed to furnish 21,000 lb. of steam per hr. at a working pressure of 425 lb. per sq. in. and 200 degrees of superheat.

The main propelling machinery consists of two units of high pressure, intermediate pressure and low pressure turbines and one astern turbine assembled in a common structure, the ahead turbines developing their rated shaft horsepower at 7000 r.p.m. The astern turbine develops 520 shaft horsepower.

Each main propelling unit consists of four impulse turbines connected to a single propeller by a two-pinion, single case double-reduction gear. These are arranged to operate as two units; that is, one high-pressure turbine, one intermediate pressure turbine and one low-pressure turbine forming a unit for ahead power, and one high-pressure turbine for astern power. The high-pressure ahead turbine rotor is mounted on the aft end of the inboard pinion shaft. The intermediate-pressure rotor



Sectional side and front elevations of marine boiler unit.

is mounted on the forward end of the inboard pinion shaft. The low-pressure rotor is mounted on the forward end of the outboard pinion shaft. The high-pressure astern rotor is mounted on the aft end of the outboard pinion shaft. Both pinions mesh with the same high-speed gear and are placed at an angle of 45 deg. to the centerline of the gear. Steam for ahead power passes through the high-pressure ahead turbine, then the intermediate-pressure turbine, then the low-pressure turbine and thence to the condenser. The astern turbine exhausts directly into the condenser; therefore when operating ahead, the astern turbine rotor revolves in a vacuum and vice versa.

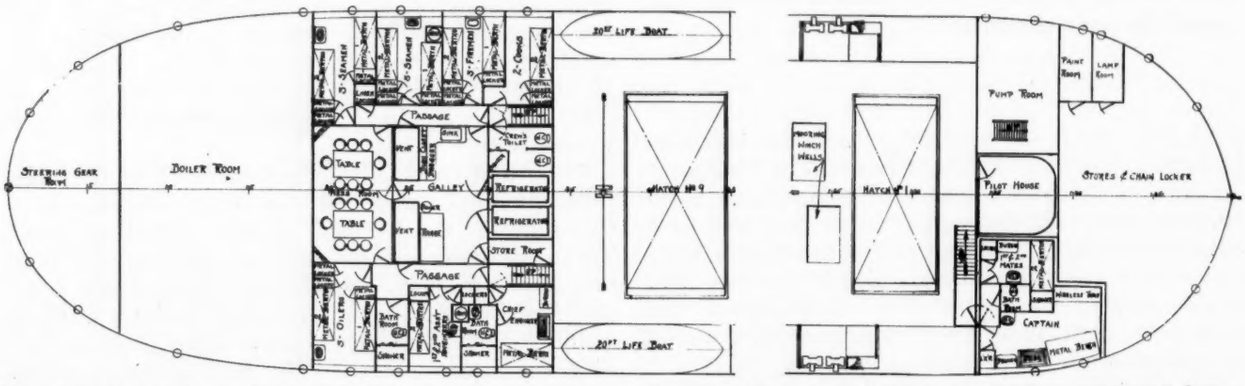
When operating with steam at 385 lb. pressure, 200 deg. fahr. superheat and exhausting at 27 in. vacuum, the ahead turbines will develop 800 s.h.p. With the same steam conditions, the astern turbine will develop 65 per cent of ahead power when operating astern at approximately 7000 r.p.m. The normal full speed of the turbines is 6979 r.p.m. which gives a propeller speed of 250 r.p.m.

The steam generating units have boilers of the two-drum type equipped with soot blowers and are baffled to provide for two-pass travel of the gases. Each boiler contains two banks of tubes of 4 in. diameter each with the exception of the first row of the lower bank which are 2 in. in diameter. The furnace is entirely water cooled with tubes of the fin type except for a small front refractory wall in which two Peabody oil burners are set.

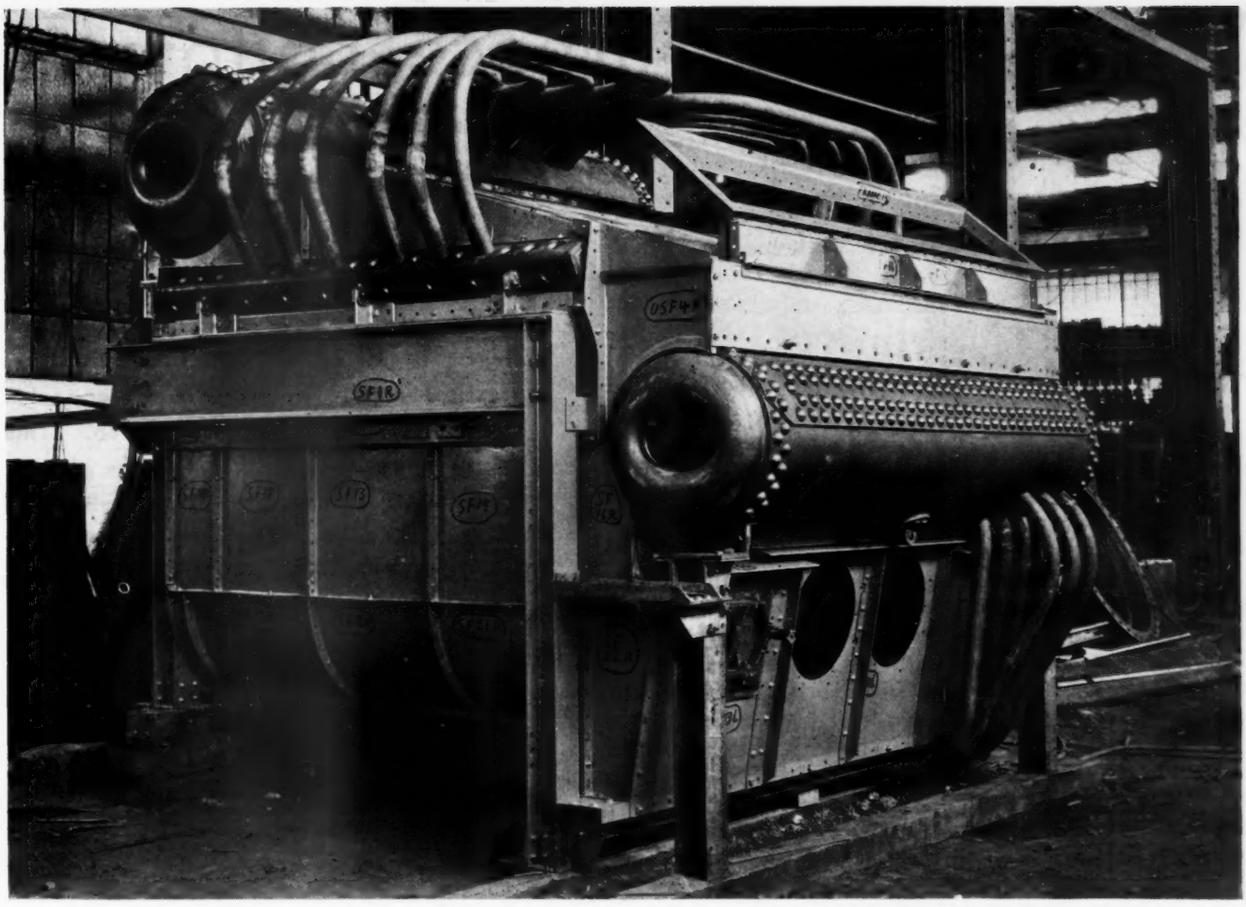
A square bottom header lies lengthwise of the furnace on the center of the furnace floor. Tubes from this header form the floor and side walls of the furnace and enter a header at each upper side wall. The rear wall is also of the fin tube construction, the tubes connecting to a header at the lower end and entering the bottom of the upper boiler drum. Both the side and rear wall furnace tubes are 3 in. O. D. with 1-inch wide fins. The centerline spacing of the tubes is 5⅛ in.

The furnace volume of 400 cu. ft. permits a heat liberation of 31,000 B.t.u. per cu. ft. per hr. when the unit is generating at the rate of 10,000 lb. of steam per hr.

A radiant type superheater is located in front of the tubes forming the rear furnace wall, the superheater elements connecting to headers outside the wall at the upper and lower points. The elements pass between the fin tubes into the furnace to a point 9 in. in front of the wall tubes. The superheater elements are a special alloy material to



Plan view of one of new Ford Cargo Ships showing forward and aft ends of ship containing crew's quarters, equipment layout, etc. The major part of the cargo space (hatches 2 to 8 inclusive) is omitted from this drawing.



Shop photograph showing assembly of 800 hp. marine boiler unit. Two of these units are installed in each ship.

withstand the high temperatures. The superheater is designed to produce 200 deg. superheat at a steam pressure of 400 lb. per sq. in.

Immediately above the upper row of the top bank of boiler tubes is the economizer, which is designed to raise the water temperature from 212 deg fahr. to 275 deg. fahr. at the 10,000 lb. evaporation point.

As shown in the several illustrations, the combined unit of furnace, boiler, superheater and economizer is most compact. It is entirely encased and well insulated. An impeller type of fan, turbine-driven, is located at the flue outlet. This fan discharges into the base of a 9-ft. high stack which is so designed that it can be swung down below the deck line into a trough lengthwise between the two boilers, the latter feature being necessary in order to permit the clearance of low bridges.

The feed pumps are geared, turbine-driven, vertical, three-stage propeller type working at full boiler pressure and 10 lb. per sq. in. back pressure. They have a water capacity of 60 g.p.m. at 550 lb. per sq. in. The feedwater heater is a 120-sq. ft. Westinghouse type capable of raising the feedwater to 230 deg. fahr. built for a working pressure of 550 lb. per sq. in.

Induced draft is furnished by two turbine-driven, propeller type fans operated at full boiler pressure, providing 20,000 lb. of air per hr. at 350 deg. fahr. against 2¾ in. static pressure.

A Copes feedwater regulator is fitted to each boiler as well as Smoot fuel and draft control.

The vessel is equipped with four Johnson-Jett automatic tension winches for handling in the locks, each driven by a 20 hp. motor. The steering gear, of Benson make, is of the transverse screw gear type steromotor with motors in duplicate. This is controlled electrically from the pilot house and on deck aft of the pilot house. Each duplicate motor is of 20 hp.

Two Benson electric warfing winches are located at bow and stern driven by 10 hp. compound wound motors.

The holds, three in number, are served by nine hatches with telescopic steel covers opened or closed by two motor-driven winches. Each hatch is 12 by 24 ft.

The power units and boilers and the crew's quarters are situated aft allowing free cargo space of 145,000 cu. ft. The pilot house device for raising and lowering to clear Barge Canal bridges consists of a hydraulic ram.

Equipment in the pilot house consists of main engines controls, magnetic and gyroscopic compasses, dual steering gear, telegraphs, controls on a ram for lowering the stack flush with the deck, searchlight controls and a chart table.

Water-Cooled Furnace Bottoms

By OTTO de LORENZI
Combustion Engineering
Corporation, New York

The design of furnace bottoms has been of primary importance in the development of pulverized fuel firing. Mr. de Lorenzi briefly traces this development and discusses several patents which have marked its various stages, beginning with the invention and practical application of the water-cooled bottom or so-called bottom screen. This patent, applied for in 1920 laid the groundwork for all later progress in pulverized fuel firing, and, as embodied in a more recent patent in conjunction with side wall cooling, is the basic feature of the modern pulverized coal fired furnace.

THE story of the development of pulverized fuel burning, is essentially that of the development of furnace design and the perfecting of methods for the prevention of the formation of objectionable slag in the furnace bottom.

As early as 1876, various attempts were made to burn coal, in pulverized form, under boilers. However it was not until many years later that any degree of success was attained. In 1910 an installation was made in Pittsburgh which developed a little less than boiler rating, with an efficiency of approximately 79 per cent. In 1913 two other installations were made and operated with partial success. However, because of slagging difficulties and the excessive maintenance cost of furnace linings, this method of firing was abandoned, and hand or stoker firing was reverted to. The failure in each of these three instances was due to two main causes—inadequate and ill disposed furnace volume—lack of means for the prevention of the formation of slag.

In 1917 an installation was made in the Oneida Street Station of The Milwaukee Electric Railway and Light Company. The boilers were provided with furnaces having relatively large volume. Vertical burners replaced the horizontal type which had been used in practically all previous installations. Notwithstanding these changes, high furnace temperatures resulted in the formation of large quantities of slag. These accumulations, along with erosion of the side walls, were the cause of frequent shut-downs. After various experiments, it was decided that the best method for freeing the furnace bottom of the slag formations, would be the installation of a means for chilling this slag before it reached the furnace hearth. To accomplish this a water screen, composed of pipes through which water is circulated, was installed near the furnace bottom.

This change in furnace design, occasioned by the installation of the simple bottom screen, more than any other single item, assured the ultimate and permanent success of pulverized fuel firing.

The effectiveness of the bottom screen, in providing a cooling zone in the lower section of the furnace, is best illustrated by the diagram shown in Fig. 1. This was taken from the test reports of the Bureau of Mines as published in Bulletin No. 223, United States Department of the Interior.

Because of the important developments occasioned by the success of the bottom screen, application for patent was filed by Henry Kreisinger, with the United States Patent Office on Oct. 22, 1920. The final patent, No. 1,463,283, was issued on July 31, 1923 and is illustrated in Fig. 2.

Using the data and experiments of the Oneida Street Station tests as a basis, the Lakeside Station of The Milwaukee Electric Railway and Light Company was designed and put into service. This was the first central station to be designed and equipped for pulverized fuel firing. After the first unit had been in service for a short time, it was found that the slag difficulties in the furnace bottom had been entirely eliminated. However, the erosion of the side and rear walls still presented a problem, requiring effective solution. The slag and ash deposited on the refractory walls and fused wherever the flames impinged. This molten slag then penetrated the refractories and formed a flux so that the furnace linings were washed away. In an attempt to overcome this difficulty, the hollow, air-cooled wall was designed. This type of construction made it possible to maintain the furnaces in service over longer operating periods.

The fact that the furnace wall temperature, due to the thin refractory lining is lowered by the air sweeping over it, has been the basis of design of the air-cooled wall. This decrease in wall temperature would cause the slag to solidify and gradually increase in thickness until the cooling effect of the air was no longer felt. Any further deposits of slag would remain in the molten state and drip off the crust already formed. The abrasion would then be slag on slag thereby saving the refractory lining. Notwithstanding the above, it was soon found that direct impingement must be avoided to prevent failure.

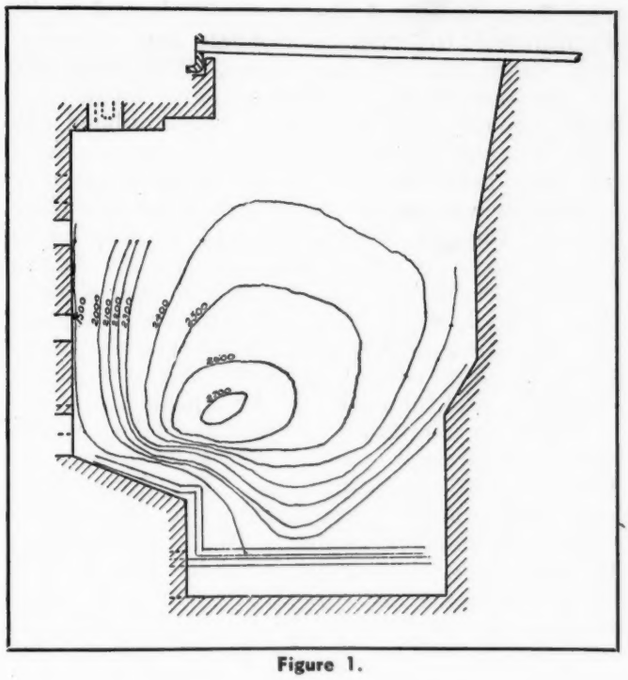


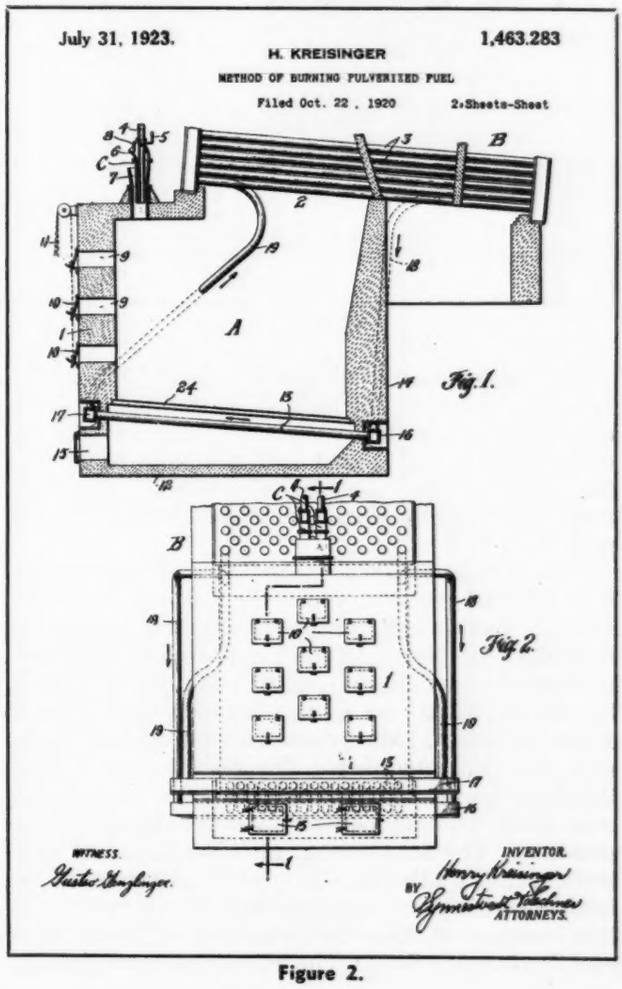
Figure 1.

During this period practically all installations were of the vertically fired type, so as to minimize turbulence and reduce the possibility of flame impingement. At the Lakeside Station, after starting up the first unit, it was found to be practically impossible to prevent the flames from sweeping over the rear walls of the furnace. Because of the success with the lower furnace screen, it was decided to apply the same remedy to the rear wall. The results were such that this type of construction became a standard basis for design.

These early experiments brought out the fact that it was possible to design and locate the vertical type of burners, with side wall air cooling, so that erosion and failure were practically eliminated. However, John E. Bell had the vision and commercial foresight to realize that a combustion chamber largely defined by water walls could be effectively used, in combination with pulverized coal. An application for patent was filed by him on September 16, 1922, which included the principle of providing water walls at the rear and the sides of a pulverized fuel fired furnace. The United States Patent Office issued patent No. 1,708,862 on April 9, 1929 and the illustration, shown as Fig. 3, is reproduced from this patent.

Since the principles, disclosed in the two foregoing patents, have been applied to furnace design, pulverized fuel has become the basis for practically all the recent central station installations. Of course, newer and different methods of firing have been developed. Turbulence has been increased so as to speed up the combustion process. Fully water-cooled furnaces have been installed, wherein the rates of heat liberation are twice and even three times as great as in some of the pioneer refractory-walled installations. Even with all this advance in design, it is still necessary to provide adequate means for cooling the ash so that the formation of slag is prevented. Installations have been made in which the cooling of the furnace bottom was omitted and the ash removed as molten slag. However the majority of installations operating and being installed are provided with some type of cooled furnace bottom.

The Kreisinger water screen patent has for its basis, among other things, to quote from U. S. Patent No. 1,463,283, "The process of burning fuel in a combustion chamber wherein the fuel is admitted in pulverized form and subjected to substantially complete combustion while in suspension therein at a temperature above the fusing point of the refuse of the fuel, in which the refuse particles precipitating out of the flame in regular operation, deposit in an ash-receiving space below the zone of combustion and are cooled in transit and while still in suspension in the chamber to a temperature at which coalescing into large solid bodies is avoided, by being subjected to the cooling effect of a water cooled screen, arranged in the combustion chamber above the point of deposit." From the above it will immediately be seen that the operation of this water screen, in cooling the ash, is continuous. Its action is also independent of the furnace temperature, as combustion occurs in the zone above the screen, while the cooling of the slag particles occurs as they pass through the screen.


July 31, 1923. 1,463,283

H. KREISINGER

METHOD OF BURNING PULVERIZED FUEL

Filed Oct. 22, 1920 2 Sheets-Sheet

Fig. 1.

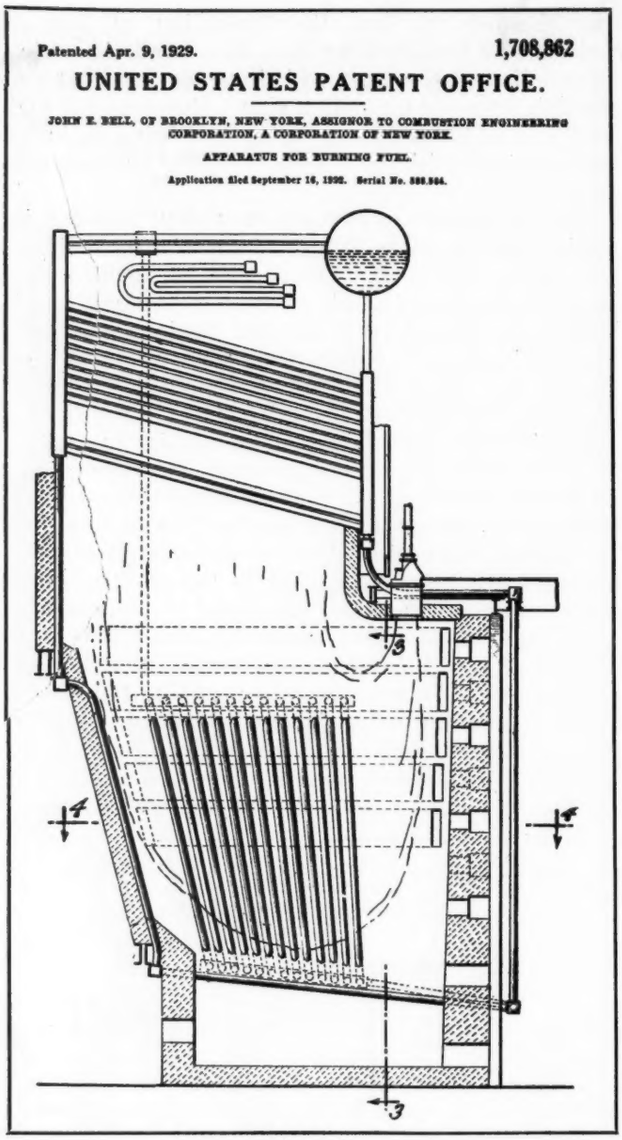
Fig. 2.

WITNESS.

INVENTOR.

ATTORNEYS.

Figure 2.



Patented Apr. 9, 1929. 1,708,862

UNITED STATES PATENT OFFICE.

JOHN E. BELL, OF BROOKLYN, NEW YORK, ASSIGNOR TO COMBUSTION ENGINEERING CORPORATION, A CORPORATION OF NEW YORK.

APPARATUS FOR BURNING FUEL.

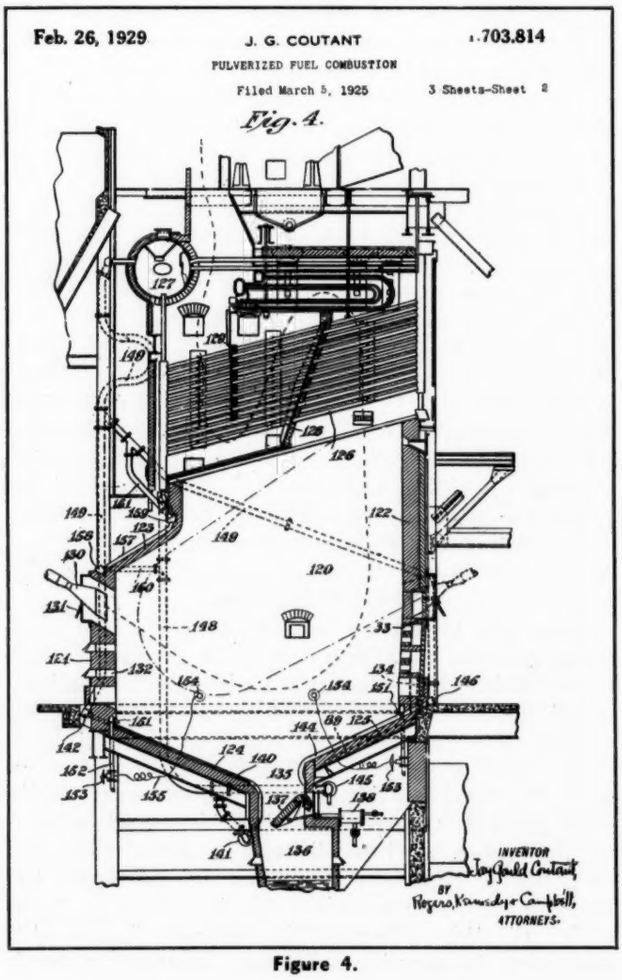
Application filed September 16, 1922. Serial No. 588,864.

Figure 3.

The United States Patent Office issued Patent No. 1,704, 814 on Feb. 26, 1929, to J. G. Coutant for a construction "primarily designed for the controlled combustion of pulverized coal, although equivalent fuel could in some cases be substituted." The illustration, shown as Fig. 4, is reproduced from this patent.

This drawing brings out the differences between this type of construction, and that of the water screen. In this instance the floor of the furnace is relatively flat. Its surface is covered with tubes connected into the boiler circulating system. A space is located in the center of the furnace, and extends across its width. This space forms the opening to an ash receiving chamber. The object in installing the floor, in the manner described above, is to secure a measure of control over the furnace temperature. The functioning of this method of control depends on the amount and effectiveness of the heat absorbing surfaces "seeing" the furnace. In this instance we have the front row of boiler tubes and the furnace floor. The effectiveness of the furnace floor, as a heat absorber, will depend on its cleanliness. In order to regulate this effectiveness, steam jets or other means, either manually or thermostatically controlled, are located in such a manner as to blow the accumulated ash into the space located across the furnace. With the bare floor exposed to the furnace gases, a considerable quantity of heat will be absorbed, and the furnace temperature will be reduced in proportion to the rate of heat absorption. As ash accumulates on the floor, the rate of heat absorption will decrease, and the furnace temperature will rise. When it reaches a predetermined point, the thermostat will place the steam jets in operation, and the cycle will be repeated.

There are a number of variable factors which enter into furnace operation, and these directly affect the furnace temperature. These variations sometimes render it troublesome, in practice, to obtain effective regulation. In the first place, furnace temperature depends on the rate of heat liberation in the furnace. If the control is set to function at a high rate of liberation, difficulty will be experienced when the furnace is operated, for any length of time, at low rates of heat release. The reason for this is that the operating personnel is apt to forget to remove periodically, the accumulated ash. In time, this deposit, if neglected, will become so thick that no cooling effect is felt from the water-



Feb. 26, 1929 J. G. COUTANT 1,703,814

PULVERIZED FUEL COMBUSTION

Filed March 5, 1925 3 Sheets-Sheet 2

Fig. 4.

INVENTOR
Jay Gould Coutant
BY
Rogers, Kennedy & Campbell,
ATTORNEYS.

Figure 4.

cooled floor. The surface of this accumulation will be fused as a result, even though the furnace temperature may be below normal. The slag masses formed will be difficult to remove and the furnace, under these conditions, differs but little from the original hearth types, without the water screen. Another factor governing furnace temperature is the percentage of excess air used to burn the fuel. If the furnace control is set to operate at a given liberation when the furnace CO_2 is 15 per cent, it will not function properly if the furnace temperature corresponds to 14 per cent CO_2. Finally the change in temperature under any given condition, that it is possible to obtain by either covering or exposing the water-cooled floor, is too small to be of any real value.

The functioning of this type of bottom is far more positive when manual operation is used.

The ash may be allowed to accumulate until there is danger of slag formations. It is then blown into the ash space and removed from the furnace. The water cooled hearth, in such cases simply acts as a medium for maintaining the ash accumulation below the fusion temperature.

The Coutant patent covers features other than the water cooled bottom and method of furnace temperature control, discussed above. However, these two are of major interest to us in this article. The floor, shown in the patent, has a slope less than the angle of repose of the ash, so that definite accumulations, which must be removed at intervals, are obtained.

A furnace bottom arrangement which not only makes higher rates of combustion possible but which is self cleaning, is shown in the reproduction, Fig. 5, of an illustration from United States Patent No. 1,811,657 issued to W. R. Wood, on June 23, 1931. From this illustration it will be seen that the furnace bottom is of the self-cleaning type, as the sides have an angle greater than the angle of repose of the ash. In addition to this feature, the exposed surface of the bottom, because it is free from ash, is capable of continually absorbing heat at very high rates. Furthermore, besides cooling the hopper section of the furnace itself, the tubes are carried part way up the vertical front and rear walls of the furnace. The effectiveness of this construction, in maintaining uniformly lower furnace temperatures and operating at higher rates of liberation, is marked. The possibility for slag accumulations in other parts of the furnace, as well as on the exposed rows of boiler tubes, is minimized. In this manner, considerable additional heat absorbing surface is provided, at very little extra cost. In order to indicate more clearly the features of this patent, one of its claims reads as follows, "In a furnace for burning finely divided fuel, in suspension, a boiler, a combustion chamber having upright walls and a hopper shaped bottom having a centrally disposed discharge orifice, two sets of closely spaced exposed tubes lining the sloping sides of the bottom and disposed at angles greater than the angle of repose of the refuse particles, and two exposed water tube wall portions lining two opposite upright wall portions adjacent the bottom of the chamber and connected in series with said tubes, the tubes and water tube wall portion being connected into the circulation of the boiler."

Pulverized fuel fired furnaces still require suitable types of bottom construction, from which ash accumulations may be readily removed. The preferable types are those in which the dust is discharged, into a storage chamber, from which it may be removed periodically. The protection of the storage chamber must be such that it is not possible for slag masses to form. Obviously the water-cooled type of construction meets these requirements, particularly if the water screen or continu-

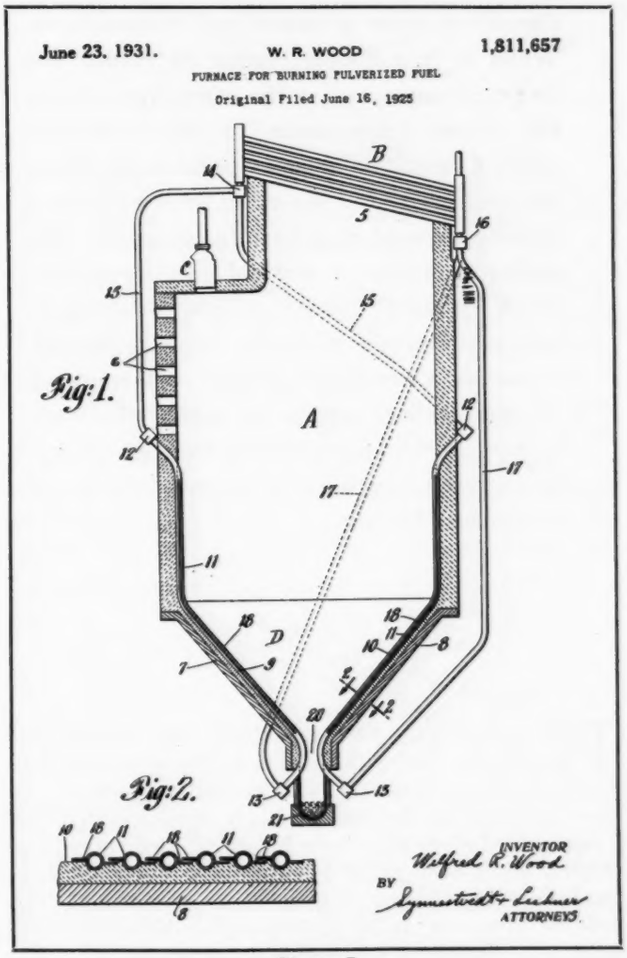


Figure 5.

ous discharge type of water-cooled hopper is used. As stated in the opening paragraph, it is well to remember that the development of pulverized fuel burning was made possible by the perfecting of methods for the prevention of slag formation in the furnace bottom. Today our furnaces are operated with increased turbulence, higher rates of heat liberation, higher CO_2 and highly preheated combustion air. All of these factors tend to accelerate the formation of slag. Therefore, it is absolutely essential that care and study be given to the design of the furnace bottom so that continuity of operation is assured.

Steam Pressure Reduction with Control of Superheat

The installation of high-pressure, steam-generating equipment in existing plants generally requires the conditioning of the high-pressure steam for use in prime movers designed for lower pressures and temperatures. While it is a simple matter to reduce the steam pressure and at the same time reduce the steam temperature to the saturation point, it is quite a complex problem to reduce the pressure and at the same time maintain a definite reduced superheat temperature. The author describes a method and equipment which has been used successfully for this purpose in a number of plants. The equipment comprises a combined pressure reducing and de-superheating system in which the high velocity of the steam passing through the reducing valve is utilized to atomize the water for de-superheating.

By T. A. PEEBLES

Vice-President in Charge of Engineering

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THE use of high pressure steam has contributed largely to the substantial reduction that has been made in the cost of generating power. In central stations the use of high pressure involves such added steps as stage bleeding and reheating, which have somewhat complicated the operating cycle and the design of generating equipment. The results, however, fully justify such additional costs and complications as have been involved.

In the industries where steam is used not only for power production but for heating and process work, the opportunities for savings often greatly exceed anything the central stations can hope to attain. In such plants definite quantities of steam, probably at different pressures and temperatures, are required in the manufacturing process. A study of the corresponding power requirements often establishes the fact that there is some pressure and temperature at which this quantity of steam can be used to generate the required amount of power in passing through a suitable prime mover with extraction at the pressures required for process work. An arrangement of this kind often hours a day during the seven warmer months and in popularity among the industrial plants.

It is impossible to maintain an exact balance between steam and power requirements for varying rates of plant output or for all seasons of the year with their varying demands for heating, and some means must be provided to give the system the required flexibility. This may be accomplished either by designing the system to deliver the steam required for process work at all times and purchasing power to make up for periods of power shortage, or designing to produce the required power and making up the deficiency of steam through a pressure reducing station. In any case a pressure reducing station is necessary to supply process steam in case the turbine is down.

In other cases, existing prime movers operating at moderate pressures and temperatures must be kept in service although the boilers from which they have previously received steam may be replaced by new units operating at higher pressures and temperatures. It, therefore, becomes necessary to take a part of the steam from the high pressure system and properly condition it for use in these existing prime movers. A number of such installations are now in successful operation handling as high as 500,000 lb. of steam per hr. through a single valve. The equipment consists of a combined pressure reducing and de-superheating system in which the high velocity of the steam passing through the reducing valve is utilized to atomize the water used for de-superheating.

Steam in flowing from a region of one pressure to a region of lower pressure travels at a velocity that is determined, for the greater part, by the pressure and temperature conditions on the two sides of the valve. With these conditions known, the velocity is readily determined and the area required to handle the desired amount of steam at this velocity is then calculated, and the valve designed

accordingly. The area through the valve is often not more than 10 or 15 per cent of the full area of the line in which it is located.

Attempts are often made to reduce steam pressure through a valve having an area equal to the area of the line in which it is placed. If only 10 to 15 per cent of this area is actually required to pass the maximum flow, a small part of the valve travel is all that can be employed for the purpose of regulation. When the steam flow is reduced far below the maximum, the valve must be near its closed position and a minute movement so greatly affects the flow that anything approaching close regulation is impossible.

The butterfly type of valve, as shown in Fig 1, is used because of its simplicity of construction and durability in operation. A valve of this type is not steam-tight, the leakage when in the closed position being about one per cent of its maximum capacity, which easily takes care of any condition except a complete shut-down, at which time a shut-off valve must be closed as it is unsafe to depend upon a tight shut-off from any valve which has been in continuous throttling service. The simplicity and durability of this construction are evidenced by the fact that while this type of valve has been used for a period of eight years, there is no record of a repair to any one of them having been necessary.

A master regulator sensitive to slight pressure changes and, at the same time, stable in its operation, is operated by an outside source of power—compressed air, oil or water—to control the valve in accordance with the pressure which is to be maintained uniform.

This arrangement gives a complete absence of enclosed operating parts that may be affected by unequal expansion due to high temperature to which the valve is subjected, and very accurate regulation is secured because the power available to move the valve is not dependent upon the extent to which the regulated pressure has departed

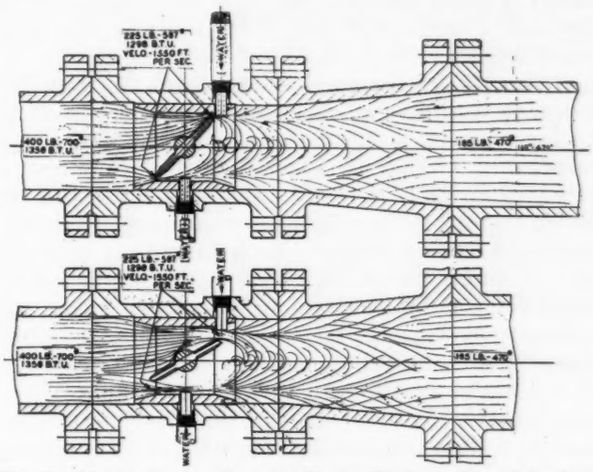

Fig. 1—Venturi type valve with butterfly damper used for pressure reduction and de-superheating.

from the standard which is to be maintained. The power cylinder of the regulator is made of ample size to handle the valve, even under adverse conditions.

Velocities of from 1000 ft. to 1500 ft. per sec. usually result at the restricted portions of the valve, and water for de-superheating is admitted adjacent to these restrictions. Steam travelling at such high velocities and being at a temperature substantially above that of the de-superheating water, instantly

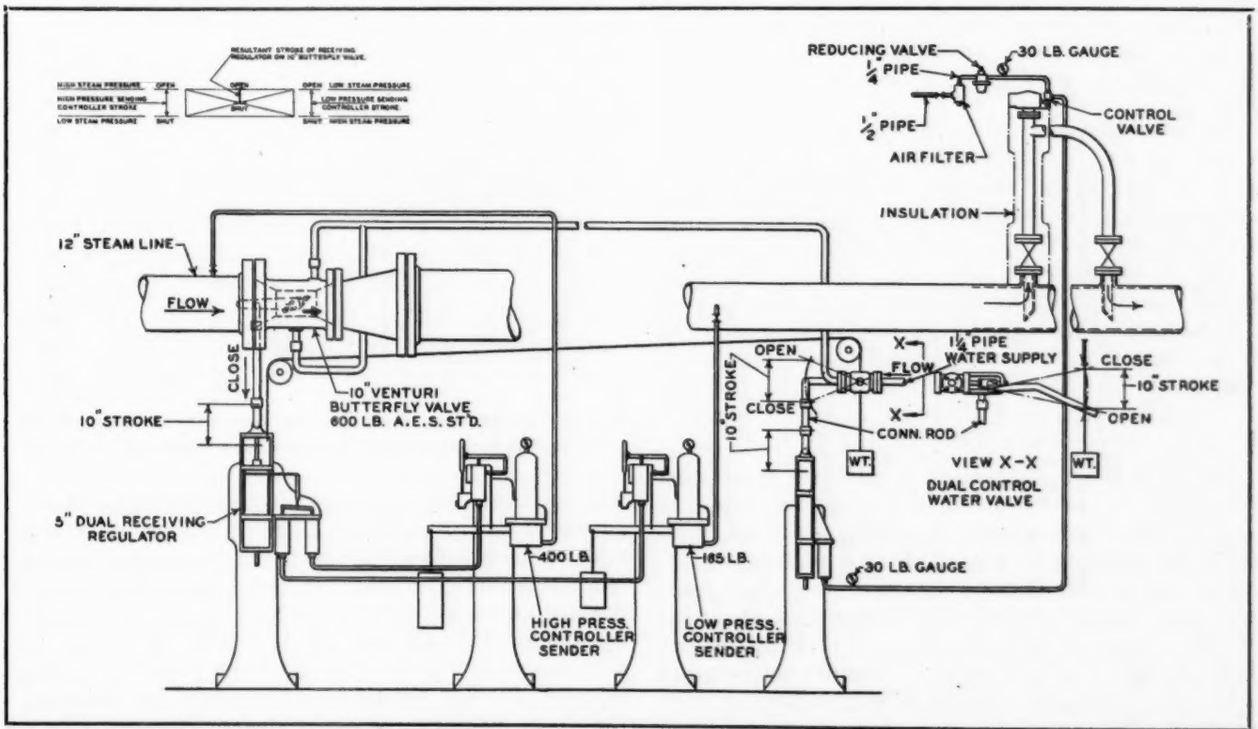

Fig. 2—Diagrammatic layout of pressure reducing and de-superheating installation. The small diagram in the upper left corner shows what happens for various combinations of high and low pressure on the high and low side of reducing valve.

breaks this water into a fine fog which is quickly absorbed by the steam; no traces of moisture being apparent at a distance of 15 ft. or 20 ft. from the point of introduction. The action of the steam and water is similar to that taking place in the automobile carbureter except that the density of the steam is much greater than that of the air flowing through a carbureter and the velocity is also very much higher.

Owing to the rapid flow of steam through the reducing and de-superheating valve, there must be no lag between a change in steam flow and a corresponding change in water flow if close temperature regulation is to result. Primary control of the water supply is therefore necessary and this control must be synchronized with variations in steam flow through the valve. This is accomplished by employing a dual control of the water valve, the primary control being secured from the same master regulator which controls the reducing valve. If conditions call for an increased opening of the steam valve, the movement of the master regulator that gives this increased opening at the same time increases the opening of the water control valve which is so adjusted that for any given position of the steam valve, the corresponding position of the water valve will put in the correct quantity of water within the limits of accuracy of such adjustment. The result is that for changing rates of steam flow there are, at the same time, corresponding changes in water flow and there is no tendency for the temperature of steam on the low pressure side to vary suddenly or through wide limits. Small variations, however, will occur due to varying superheat in the steam leaving the boilers and to the fact that changes in the pressure of high pressure steam or water will affect the relative flows and to correct for the variations that occur, a thermostatic element is used to control the secondary or vernier adjustment of the water valve.

The thermostat consists of a bi-metallic element which operates an escapement valve to send a control pressure to the regulator which makes these secondary adjustments on the water valve. Since the temperature changes that must be compensated for in this manner are small and do not occur suddenly, the thermostat can be made sensitive to slight changes with the result that close regulation of the final temperature is secured with stable operation of the entire control system. The thermostat and the regulator through which it controls the water supply are illustrated in Fig. 2.

Fig. 2 further illustrates a feature that must sometimes be incorporated in a pressure reducing and de-superheating station. This drawing illustrates the equipment installed in a plant generating steam at 400 lb. and 700 deg. fahr. temperature, and using a substantial amount of steam at 165 lb. pressure and 470 deg. total temperature. High pressure boilers supply steam to turbines and only the excess goes to the low pressure system, which at the same time may receive steam from boilers operating at the lower pressure. At times the demands exceed the capacity of the high pressure boilers but the pressure must be maintained at the prime movers. This is accomplished by the use of two master regulators, both acting to control a third regulator which operates the butterfly valve. Under normal conditions the regulator operating the valve is controlled entirely from the

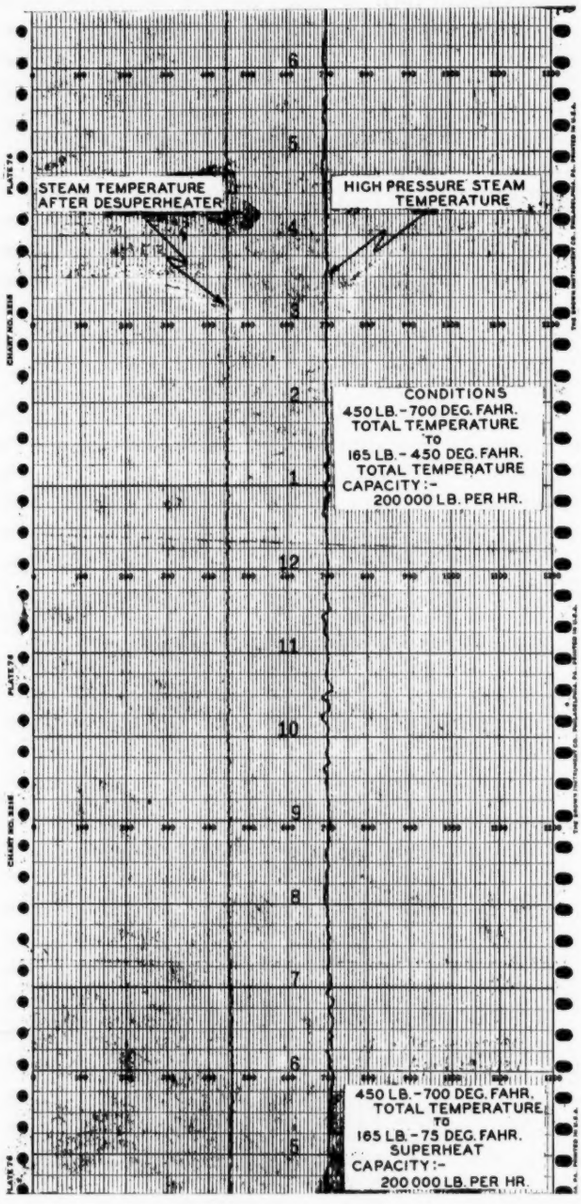
STEAM TEMPERATURE AFTER DESUPERHEATER
HIGH PRESSURE STEAM TEMPERATURE
CONDITIONS
450 LB. - 700 DEG. FAHR. TOTAL TEMPERATURE
TO
165 LB. - 450 DEG. FAHR. TOTAL TEMPERATURE
CAPACITY :-
200 000 LB. PER HR.
450 LB. - 700 DEG. FAHR. TOTAL TEMPERATURE
TO
165 LB. - 75 DEG. FAHR. SUPERHEAT
CAPACITY :-
200 000 LB. PER HR.

Fig. 3—Temperature chart showing temperatures entering and leaving the de-superheater for installation illustrated in Fig. 2.

master regulator responsive to the 165 lb. pressure. However, if the pressure on the high pressure side should drop below 400 lb. the high pressure master takes control of the regulator operating the reducing valve, causing it to check until the amount of steam flowing through is just that amount which can be taken from the high pressure system without further reduction of pressure. In this way the high pressure prime movers are insured an

(*Continued on page 61*)

Typical Solid and Liquid Fuels*

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This is the third article by the author in the group dealing with fuels and their combustion. It presents a comparison of the air required for combustion and the products produced for practically all solid and liquid fuels that are of any industrial importance in this country. The accompanying curves and tables are of particular value for the reason that it is frequently difficult to locate reliable analyses of all the different fuels. Frequently, such data are not given in terms of ultimate chemical composition which information is required in making many important calculations . . . . The next article in this series will be on the subject of gaseous fuels.

THE fuels burned in industrial and domestic furnaces and in internal combustion engines have such a variety of characteristics that it is in general necessary to design combustion apparatus for the particular fuel to be used. Typical compositions and heating values can be selected, however, for guidance in design calculations and for comparison of the properties of the various fuels available.

Growing vegetation was for many ages man's only source of fuel; but with the discovery in recent times of coal, oil and gas within the earth's surface, his supply of fuels has been greatly increased. Modern civilization is based on a wide utilization of such fuels, often in their natural states but frequently manufactured into other forms for more convenient use. In certain industrial processes, waste materials are produced which are employed as fuel in those industries.

All these available natural, manufactured and waste fuels can be classified as solid, liquid or gaseous. In considering combustion reactions, it is preferable to deal with gaseous fuels differently from solid and liquid fuels. The present article will therefore be confined to solid and liquid fuels, for which typical compositions and heating values will be given. A method will be illustrated for calculating the weight, volume, density, specific heat and sensible heat of the air required for combustion and of the products produced. Curves will be included to compare the various typical solid and liquid fuels. Gaseous fuels will be treated in an article to follow.

Wood and Other Growing Vegetation

Wood and other growing vegetation have as their basis cellulose; but the presence of resins, gums, oils, etc., causes the percentages of carbon, hydrogen and oxygen to be somewhat different from that indicated by the chemical formula for cellulose $C_6H_{10}O_5$. The small quantities of nitrogen and sulphur present may be neglected in combustion calculations, but the amount of ash is sufficient to receive consideration and allowances must be made for large variations in moisture content.

Green wood contains about 50 per cent. moisture. After air drying for three months, the moisture is reduced to about 35 per cent. In thoroughly seasoned wood, the moisture is about 20 per cent. By kiln drying, the moisture can be reduced to less than 5 per cent; but when kiln dried wood is exposed to the atmosphere, moisture is reabsorbed until it amounts to 10 or 15 per cent. When lumber has been steamed for veneering, it may contain as high as 80 per cent moisture. Ordinary dry cord wood contains about 25 per cent. moisture.

The heating value of dry wood varies with the kind of wood. Thus, pine, fir, spruce, cedar, hemlock and redwood have a heating value of about 9000 B.t.u. per lb. of dry wood, beech and birch about 8600, ash and elm about 8500, oak about 8300, willow about 7900 and poplar about 7800 B.t.u. A heating value of 8800 B.t.u. per lb. of dry wood has been selected as typical and the data in Table I have been prepared to show the variation in heating value with moisture content. The lower heating value under constant pressure has been calculated from the upper heating value at constant volume by the method explained in the article on "Composition and Heating Value of Fuels." The lower heating value shows how the effectiveness of wood fuel decreases with increase of moisture content.

Wood is important as a fuel in certain wood working industries where there is more or less waste product. Bagasse and tan bark are similar waste materials available as fuels in the sugar and tanning industries. The former is the refuse of sugar cane from which the juice has been extracted and it contains approximately one-half water. The latter is the fibrous portion of oak bark remaining after its use in tanning, and it contains about two-

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thirds water. Typical compositions and heating values are given in Table I.

Straw and corn have been used to a limited extent as fuels in agricultural communities; but as these fuels are not important industrially, typical compositions will not be given.

Charcoal is manufactured by the destructive distillation of wood, an industry dating back to prehistoric times. Originally, charcoal was the only product, none of the vapors distilled off being recovered. Since the substitution of coke for charcoal in smelting iron in the blast furnace, however, charcoal has become the by-product available as a waste fuel in the wood distillation industry in which the principal products are acetates, alcohol and tar. A typical composition and heating value of wood charcoal are given in Table II.

The alcohol obtained by distillation of wood is known as wood, or methyl, alcohol. It is also manufactured by the reaction of water gas and steam in the presence of a catalyst when it is known as methanol. The chemical composition and physical properties of methyl alcohol differ from those of ethyl, or grain, alcohol originally obtained from grains. Ethyl alcohol is made by fermentation of sugar. Sugarcane molasses is the chief raw material; corn is next in importance; potatoes, sugar beets, etc., are also used. Alcohol can be employed as a fuel in internal combustion engines but cannot compete economically with gasoline at the present price of the latter. Blends of alcohol with gasoline and with benzol have, however, been on the market, the former in the United States and the latter in Europe.

The composition of methyl alcohol is represented by the chemical formula CH_4O and its heating value water free is 307,600 B.t.u. per lb.-mole. Ethyl alcohol is represented by C_2H_6O and has a heating value water free of 590,400 B.t.u. per lb.-mole. Except when treated with lime or other drying agent, however, alcohol contains more or less water because by distillation alone the moisture cannot be reduced much below 9 per cent by weight (5 per cent by volume). Typical analyses and heating values are given in Table I.

Coal and Fuels Derived Therefrom

Coal is the result of vegetable matter being submerged and then subjected to elevated pressure and temperature through geological periods of time. By reason of the various sources of such vegetable matter and of the different conditions to which it has been submitted, a variety of products has resulted varying from peat and lignite through the several grades of bituminous coal to anthracite and graphitic coal. In the eastern part of the United States, there is a fairly regular gradation in properties of this natural fuel from the graphitic coal of Rhode Island through the anthracite coal of eastern Pennsylvania and the semi-anthracite and semi-bituminous coals of middle Pennsylvania, Maryland and West Virginia to the bituminous coals of western Pennsylvania, West Virginia, Ohio and Kentucky. The middle western coals of Indiana, Illinois, Iowa, Missouri and Kansas are all in the bituminous class. Lignite occurs in the Dakotas and in Texas. The western coals of Wyoming, Colorado and Arkansas vary greatly in characteristics within short distances due to the varying disturbances experienced in this region during the coal formation periods.

The seven examples given in Table II may be taken as representative of the various grades of this fuel used in the United States for combustion in industrial furnaces. The data for anthracite coal apply to the fine sizes burned in industrial furnaces rather than to the higher grades burned in domestic furnaces. Peat has not been included because it has no industrial importance in this country.

Coal is mostly used in its natural condition. In countries where lump coal is not readily available for domestic consumption, slack coal may be briquetted by use of suitable binding material such as pitch. Coke was first made from coal by destructive distillation 200 or 300 years ago to displace wood charcoal as a fuel in the iron blast furnace. No attempt was made to recover the gases and vapors driven off during the process. The distillation of coal primarily for the production of city gas dates back somewhat more than 100 years. In the coal carbonization process as now conducted for either purpose, the recovered products generally comprise tar, light oils and ammonia as well as gas and coke.

In order to secure a dense coke capable of supporting the burden in the blast furnace or to obtain the maximum yield of gas for city purposes, high distillation temperatures of 1800 to 2100 fahr. are usually employed in coal carbonization. Low temperature carbonization of coal at 1000 to 1400 fahr. has been advocated in order to produce a better coke for domestic consumption and a larger yield of light oils and tar. In the manufacture of coke, more or less fines are produced, called coke breeze, which is not salable for metallurgical or domestic purposes but which may be burned on grates as a waste fuel in the coal carbonization industry. Typical analyses of coke are given in Table II.

The coal tar recovered as a by-product in the carbonization of coal is sometimes burned as a fuel in the crude state, particularly in metallurgical furnaces where a luminous flame is desired. A large portion of such tar, however, is fractionated by distillation into light oil, middle oil, heavy oil and pitch or coke. The light oil fraction, called benzol, is often used as a fuel in internal combustion engines either alone or mixed with alcohol or gasoline. It is not pure benzol but contains toluol and heavier hydrocarbons. Commercial 90 per cent benzol, for example, contains about 70 per cent of benzol, 24 per cent of toluol and 6 per cent of heavier hydrocarbons, the "90 per cent" referring to the portion of the liquid which will distill over up to a temperature of 100 cent. when heated under specified conditions. The heavier tar oil fractions may be used as fuels in Diesel en-

gines. The pitch or coke is at times burned as a fuel in the coal tar industry. Typical compositions and heating values of coal tar and its products are given in Table III.

Petroleum and Its Products

Petroleum is a natural liquid fuel which is sometimes burned in its crude state as taken from the ground; but it is generally subjected to some refining process by reason of the value of the gasoline obtained by distillation and by cracking or hydrogenation of the crude oil. Most of the fractions obtained by the commercial distillation of petroleum are used as fuels and are designated as gasoline, kerosene, gas oil, fuel oil, Diesel engine oil, etc. A certain amount of fixed gas is also produced in the cracking operation and separated by distillation, but this refinery gas will not be further considered in the present article. The heating value of petroleum and its liquid products is related to the specific gravity as explained in the preceding article on "Composition and Heating Value of Fuels." Typical compositions and heating values of petroleum products are given in Table III.

Gasoline, the principal fuel for internal combustion engines, has an A.P.I. (American Petroleum Institute) gravity varying from 55 to 65 degrees. A gravity of 60 degrees A.P.I. has been selected as typical of this light fraction of petroleum although the average motor gasoline sold in the United States is probably nearer 58 degrees A.P.I. When obtained from natural gas by compression and cooling or by absorption in oil or charcoal, it is called natural gasoline to distinguish it from straight run gasoline or cracked gasoline obtained from crude petroleum. Kerosene, the next heavier fraction of crude oil, is used in stoves and lamps as well as a fuel in internal combustion engines, and has a gravity from 45 to 48 degrees A.P. I. A gravity of 30 degrees A.P.I. has been taken as representative of gas oil, which was so named because this fraction of petroleum was at one time used mainly for enriching illuminating gas.

Six grades of fuel oil are specified by the American Oil Burner Association. Grades 1, 2 and 3 are designated as light, medium and heavy domestic fuel oil and are specified mainly by the end temperatures of the distillation range; the viscosity is also specified for grade 3. Grades 4, 5 and 6 are designated as light, medium and heavy industrial fuel oil and are specified mainly by the viscosity. The gravities of these several grades of fuel oil are not specified because the gravity will vary with the source of the crude oil and the extent of the refinery operations in cracking and distilling. Fuel oil may therefore be a light petroleum fraction similar to kerosene or gas oil, or it may be a heavy residue left after distilling off the fixed gas, the gasoline and more or less of the kerosene and gas oil. The compositions and heating values given in Table III for kerosene and gas oil may be taken as representative of the lighter fuel oils. To represent the heavier industrial fuel oils, a composition and heating value have been tabulated for 15-degree A.P.I. fuel oil.

Diesel engine oil also varies in properties from kerosene to a heavy petroleum fraction or residue so that the compositions and heating values of kerosene, gas oil and fuel oil given in Table III may be taken as typical of Diesel engine oils.

Petroleum coke is the residue left by cracking or by carrying the distillation of crude oil sufficiently far. A typical composition and heating value are given in Table III. If the distillation be stopped somewhat earlier, the residue may be fluid at the still temperature but solid at room temperature. Such a residue would be similar to coal tar pitch and have properties intermediate to those given for coke and fuel oil.

Sludge is a waste material in oil refineries resulting from purification of petroleum products with sulphuric acid. It may contain 20 to 50 per cent or more of acid and water and appreciable amounts of ash. The sulphur content will depend upon the efficiency of any acid recovery process that might be used. The combustible matter can be taken as intermediate to coke and fuel oil, so that for any given acid, water and ash content, a representative composition and heating value can be prepared from the data in Table III.

Oil Shale

Oil shale is a rock formed by the consolidation of silt or clay and impregnated with bituminous matter which yields oil and tar by destructive distillation. Workable deposits occur in Colorado and adjacent states and considerable study has been given to its possible use. Although oil shale is employed as a fuel in certain foreign countries, its use as a fuel in this country is uneconomical in competition with coal by reason of its high ash content, 50 per cent or more. No typical composition is therefore given.

City Wastes

City wastes comprise ashes, rubbish, garbage and sewage, of which the first three can be used as fuels. The suspended matter in sewage can also be so used if recovered, having when dried, an average heat of combustion of about 6,500 B.t.u. per lb. In Europe, ashes from municipalities are used as fuel after screening to remove dust and dirt, the cinders recovered containing about one-half combustible matter. In the United States, such ashes are seldom used for fuel but are generally carted to city or private dumps to fill in undeveloped land.

Rubbish consists of wastes from paper, wood and other cellulosic composites mixed with coarse incombustible materials such as metal, glass and dirt, the latter amounting to 20 to 60 per cent of the total weight. Three-quarters of the combustible material in municipal rubbish is derived from paper made from wood pulp, so that for combustion calculations, the ultimate analysis may be taken approximately the same as given for wood, but with a heating value corresponding to non-

TABLE I. COMPOSITION AND HEATING VALUE OF WOOD, BAGASSE, TAN BARK AND ALCOHOL

	Wood				Bagasse		Tan bark		Methyl alcohol		Ethyl alcohol	
	Dry	Seasoned	Green	Steamed	Dry	As fired	Dry	As fired	Chemically dry	As distilled	Chemically dry	As distilled
Reference No.	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	L-1	L-2	L-3	L-4
Moisture, per cent	0.0	25.0	50.0	75.0	0.0	50.0	0.0	66.7	....	10.0	....	10.0
Ash, per cent	0.8	0.6	0.4	0.2	2.0	1.0	1.5	0.5	....	....	....	....
Carbon, per cent	49.6	37.2	24.8	12.4	45.0	22.5	52.0	17.3	37.5	33.7	52.1	46.9
Hydrogen, per cent	6.0	4.5	3.0	1.5	6.0	3.0	6.0	2.0	12.5	11.3	13.1	11.8
Oxygen, per cent	43.6	32.7	21.8	10.9	47.0	23.5	40.5	13.5	50.0	45.0	34.8	31.3
Upper heating value at constant volume, B.t.u. per lb.	8800	6600	4400	2200	8300	4150	9300	3100	9600	8640	12820	11540
Lower heating value under constant pressure, B.t.u. per lb.	8203	5875	3547	1220	7702	3296	8704	2163	8370	7417	11540	10273

TABLE II. COMPOSITION AND HEATING VALUE OF COAL, COKE AND CHARCOAL

	Pennsylvania anthracite steaming coal	Pocahontas and New River semi-bituminous coal	Pittsburgh bituminous coal	Illinois high-grade bituminous coal	Iowa and Illinois low-grade bituminous coal	Wyoming sub-bituminous coal	Texas lignite	High temperature coke	High temperature coke breeze	Low temperature coke	Wood charcoal
Reference No.	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18	S-19
Volatile matter in combustible, per cent	6.0	19.0	36.0	47.0	51.0	45.0	60.0	1.5	6.0	13.0	21.5
Upper heating value of combustible, B.t.u. per lb.	15000	15770	15300	14570	14150	12960	12940	14400	14600	14800	13900
Ash in dry fuel, per cent	18.4	6.7	8.7	10.0	16.3	15.5	17.2	10.5	22.0	10.2	4.1
Ash fusion temp., fahr.	2400	2500	2200	2200	2000	2200	2200	....	....	....	....
Moisture, per cent	2.0	2.8	3.4	10.0	13.9	22.4	34.7	5.0	12.0	2.0	3.2
Air drying loss, per cent	1.5	2.1	2.4	6.0	9.9	12.4	24.7	....	....	....	....
Ultimate analysis as fired:											
Moisture, per cent	2.0	2.8	3.4	10.0	13.9	22.4	34.7	5.0	12.0	2.0	3.2
Ash, per cent	18.0	6.5	8.4	9.0	14.0	12.0	11.2	10.0	18.0	10.0	4.0
Carbon, per cent	75.5	81.3	74.4	63.2	54.7	48.1	39.3	82.0	66.8	77.0	78.7
Hydrogen, per cent	2.0	4.4	4.7	4.6	4.0	3.5	3.0	0.5	1.2	3.6	3.3
Sulphur, per cent	0.5	0.9	1.0	4.0	6.2	1.1	0.8	0.8	0.6	1.4	0.1
Nitrogen, per cent	0.8	1.2	1.4	1.1	0.8	1.1	0.7	1.0	0.9	0.5	0.4
Oxygen, per cent	1.2	2.9	6.7	8.1	6.4	11.8	10.3	0.7	0.5	5.5	10.3
Upper heating value at constant volume, B.t.u. per lb.	12000	14300	13500	11800	10200	8500	7000	12200	10200	13000	12900
Lower heating value under constant pressure, B.t.u. per lb.	11783	13840	13003	11239	9655	7908	6320	12095	9950	12626	12540

TABLE III. COMPOSITION AND HEATING VALUE OF COAL TAR AND PETROLEUM PRODUCTS

	Coal tar products					Petroleum products				
	Coke oven crude tar	Commercial 90 per cent benzol	Commercial tar oil	Coal tar pitch	Coal tar coke	60-degree A. P. I. gasolene	45-degree A. P. I. kerosene	30-degree A. P. I. gas oil	15-degree A. P. I. fuel oil	Petroleum coke
Reference No.	L-5	L-6	L-7	S-20	S-21	L-8	L-9	L-10	L-11	S-22
Moisture, per cent	2.5	....	....	....	....	....	....	....	....	....
Ash, per cent	Trace	....	....	0.4	0.6	....	....	....	....	0.2
Carbon, per cent	88.5	90.0	89.4	92.0	94.0	85.0	85.0	85.0	85.5	94.0
Hydrogen, per cent	5.5	7.8	6.9	4.4	2.6	14.8	14.0	12.8	11.5	2.6
Sulphur, per cent	0.8	0.4	0.6	0.9	0.9	....	....	0.8	1.6	1.6
Nitrogen, per cent	1.0	0.6	1.0	1.1	1.1	0.1	0.5	0.7	0.7	0.8
Oxygen, per cent	1.7	1.2	2.1	1.2	0.8	0.1	0.5	0.7	0.7	0.8
Upper heating value at constant volume, B.t.u. per lb.	15600	17500	16200	15800	15200	20200	19900	19300	18500	15200
Lower heating value under constant pressure, B.t.u. per lb.	15037	16742	15529	15372	14946	18762	18540	18056	17383	14947

resinous wood, about 8,300 B.t.u. per lb. of moisture and ash free rubbish. A typical rubbish may be assumed to contain between 4 and 5 per cent of moisture, the same amount of true ash and about 38 per cent of coarse and separable incombustible constituents.

Garbage is derived from the food supply of cities and its composition is conveniently expressed in terms of protein, fat and carbohydrate rather than by giving its ultimate chemical analysis. The latter has been determined for the basic food constituents so frequently in different laboratories with concordant results, that such results may be used to calculate the elementary composition of garbage from its proportions of protein, fat and carbohydrate. Typical elementary compositions of the three basic constituents of foods are:

	Protein (Meat)	Fat (Animal)	Carbohydrate (Cellulose, starch, sugars, etc.)
Carbon, per cent	52.8	76.5	44.4
Hydrogen, per cent	7.1	12.0	6.2
Oxygen, per cent	22.0	11.5	49.4
Nitrogen, per cent	16.7	0.0	0.0
Sulphur, per cent	1.3	0.0	0.0
Upper heating value, B.t.u. per lb.	10170	17010	7380

Average garbage may be taken to contain: Ash 3.3 per cent., protein 4.0 per cent., fat 4.9 per cent., and carbohydrate 12.8 per cent. The water content is high, varying from 60 to 80 per cent with an average of 75 per cent. The ultimate composition for combustion calculations is given in Table IV. With its high moisture content, garbage is neither ignitible nor combustible, unless combined with rubbish or other auxiliary fuel. A mixture of garbage and rubbish is called "mixed refuse," and the natural proportions are usually two to one, by weight. The low heating values of city wastes suggest the desirability of removing the coarse incombustible constituents from rubbish, which is standard practice in Europe, and of pre-drying garbage for the preparation of a higher grade of fuel.

Combustion Calculations

For the combustion of any one of these typical fuels, a certain amount of oxygen is theoretically required for complete combustion. Usually, "excess air" over that containing the theoretically required quantity of oxygen, is actually supplied for combustion. Since combustion conditions are generally judged by the percentage of carbon dioxide in the products, it is of interest to calculate the excess air percentages for the various typical fuels corresponding to different percentages of carbon dioxide because the excess air percentage is often assumed in design calculations. It is possible, however, to calculate the air to be supplied for combustion and the products produced for any given carbon dioxide percentage without determining the excess air percentage. This is illustrated in Table V. for Pittsburgh bituminous coal.

The first column of Table V. contains the chemical symbol for the constituent of which the weight per pound of fuel fired is given in the second column. The moles of oxygen required for each constituent are given in the third column. The remaining columns contain the moles of products classified as required for further calculations.

TABLE IV. COMPOSITION AND HEATING VALUE OF CITY WASTES

	Rubbish	Garbage	Mixed refuse
Reference No.	S-23	S-24	S-25
Moisture, per cent	4.5	75.0	51.5
Ash, per cent.	41.5	3.3	16.0
Carbon, per cent	27.0	11.5	16.7
Hydrogen, per cent	3.3	1.7	2.2
Sulphur, per cent.	(0.10)	(0.05)	(0.07)
Nitrogen, per cent	...	0.7	0.5
Oxygen, per cent	23.7	7.8	13.1
Upper heating value at constant volume, B.t.u. per lb.	4536	2200	2979
Lower heating value under constant pressure, B.t.u. per lb.	4159	1201	2190

Based on the chemical formulas for the combustion reactions of oxygen with carbon, hydrogen and sulphur, given in the preceding article entitled, "Combustion Heat Balance," the moles of oxygen theoretically required for complete combustion are found as tabulated in the third column of Table V. by dividing the weight of carbon by 12, the weight of hydrogen by 4 and the weight of sulphur by 32; thus, $0.744/12 = 0.0620$ mole of O_2 required for the carbon C, $0.047/4 = 0.0118$ mole of O_2 required for the hydrogen H and $0.010/32 = 0.0003$ mole of O_2 required for the sulphur S. The moles of oxygen corresponding to the weight of oxygen in the fuel are found by dividing the latter by 32; that is, $0.067/32 = 0.0021$ mole of O_2 from the fuel. This value must be subtracted from the sum of the other three values in order to find the moles of oxygen theoretically required per pound of fuel fired; thus, $0.0620 + 0.0118 + 0.0003 - 0.0021 = 0.0720$ mole of O_2 theoretically required per pound of Pittsburgh bituminous coal.

TABLE V. COMBUSTION CALCULATIONS FOR PITTSBURGH BITUMINOUS COAL WITH 15 PER CENT CO_2

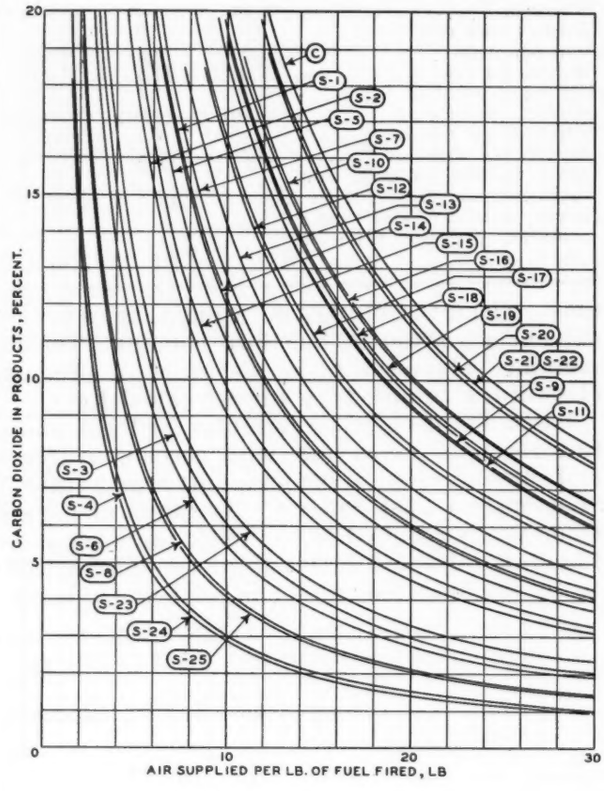
Symbol	Weight fraction	O_2 regd. moles	CO_2	SO_2	N_2	O_2	H_2O
H_2O	0.034	.....	.....	.....	.....	.....	0.0019
Ash	0.084	.....	.....	.....	.....	.....	.....
C	0.744	0.0620	0.0620	.....	.....	.....	.....
H	0.047	0.0118	.....	.....	.....	.....	0.0235
S	0.010	0.0003	.....	0.0003	.....	.....	.....
N	0.014	.....	.....	.....	0.0005	.....	.....
O	0.067—0.0021		.....	.....	.....	.....	.....
O_2 from air		0.0720	.....	.....	.....	.....	.....
N_2 from air		0.2709	.....	.....	0.2709	.....	.....
Theor. dry air	0.3429		.....	.....	.....	.....	.....
H_2O in theor. air		.....			..	.....	0.0060
Theor. products		.....	0.0620	0.0003	0.2714	..	0.0314
Excess dry air	0.0816		.....	.....	0.0645	0.0171	.....
H_2O in excess air		.....	.....	.....	.....	.....	0.0014
Actual dry air	0.4245	0.0620	0.0003		0.3359	0.0171	0.0328
H_2O in actual air		0.0074		0.0623		0.3530	
0.0623/0.15 =					0.4153		

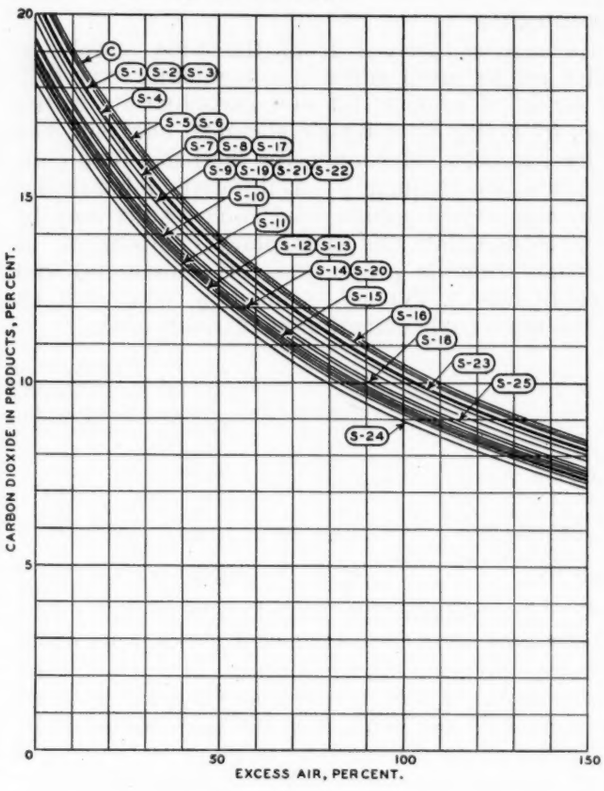
Based on the chemical formulas for the combustion reactions of oxygen with carbon, hydrogen and sulphur, given in the preceding article entitled, "Combustion Heat Balance," the moles of oxygen theoretically required for complete combustion are found as tabulated in the third column of Table V. by dividing the weight of carbon by 12, the weight of hydrogen by 4 and the weight of sulphur by 32; thus, $0.744/12 = 0.0620$ mole of O_2 required for the carbon C, $0.047/4 = 0.0118$ mole of O_2 required for the hydrogen H and $0.010/32 = 0.0003$ mole of O_2 required for the sulphur S. The moles of oxygen corresponding to the weight of oxygen in the fuel are found by dividing the latter by 32; that is, $0.067/32 = 0.0021$ mole of O_2 from the fuel. This value must be subtracted from the sum of the other three values in order to find the moles of oxygen theoretically required per pound of fuel fired; thus, $0.0620 + 0.0118 + 0.0003 - 0.0021 = 0.0720$ mole of O_2 theoretically required per pound of Pittsburgh bituminous coal.

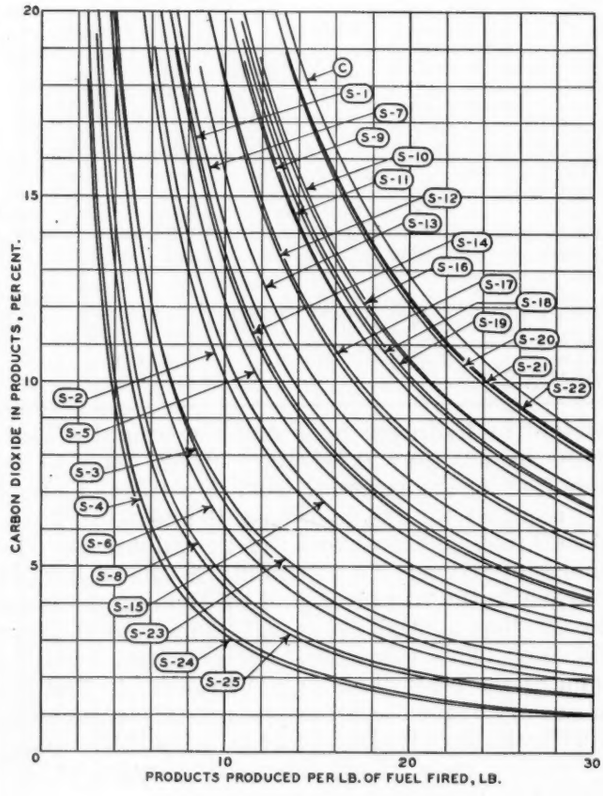
(*Continued on page 30*)

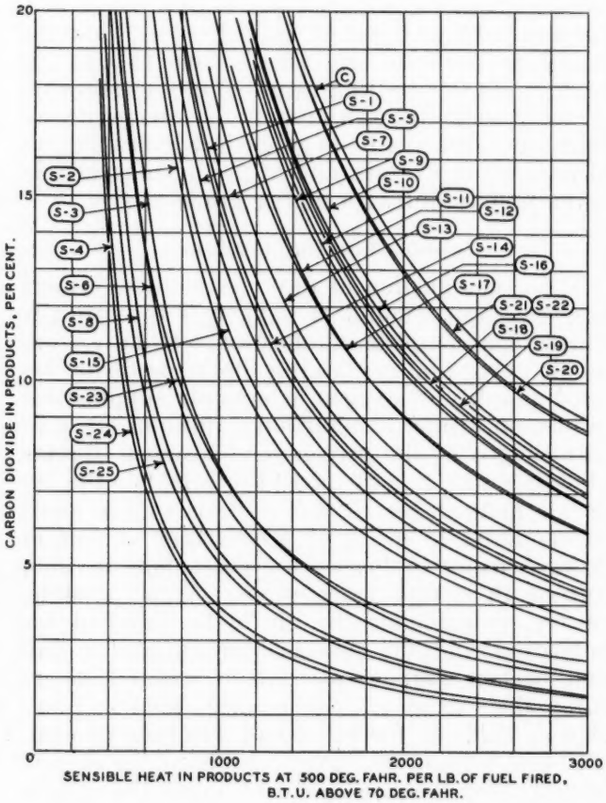
TYPICAL SOLID FUELS

Curve numbers correspond with reference numbers in Tables I, II, III and IV



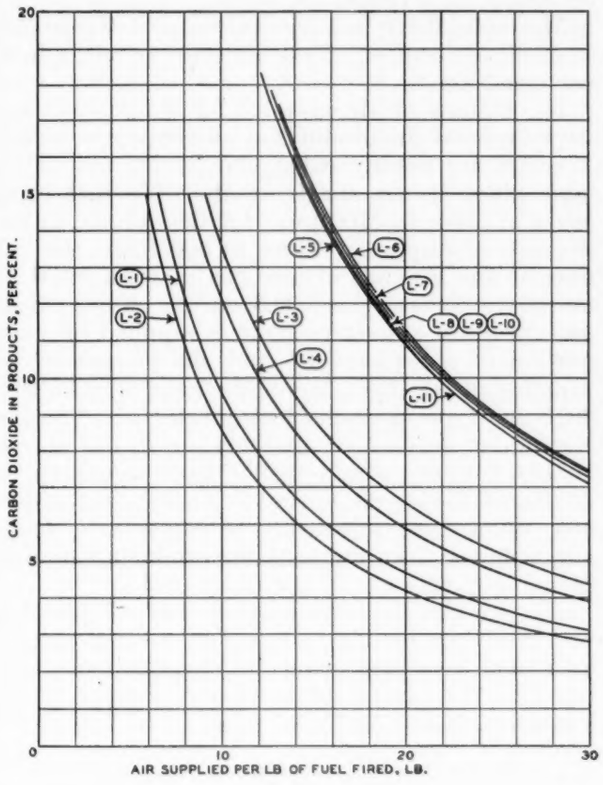


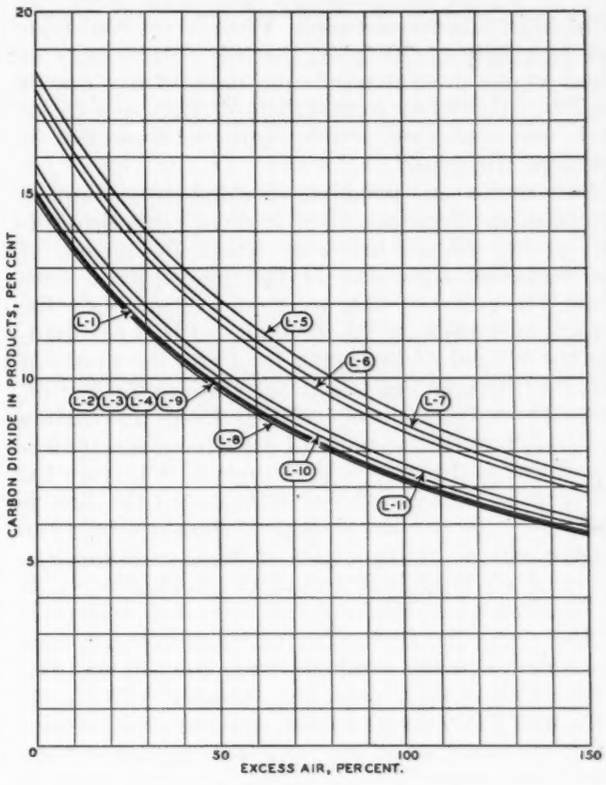


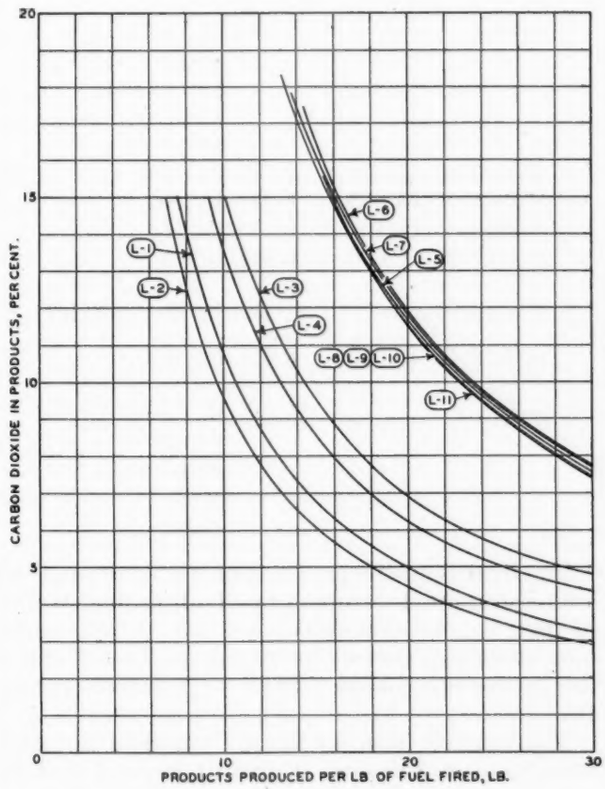


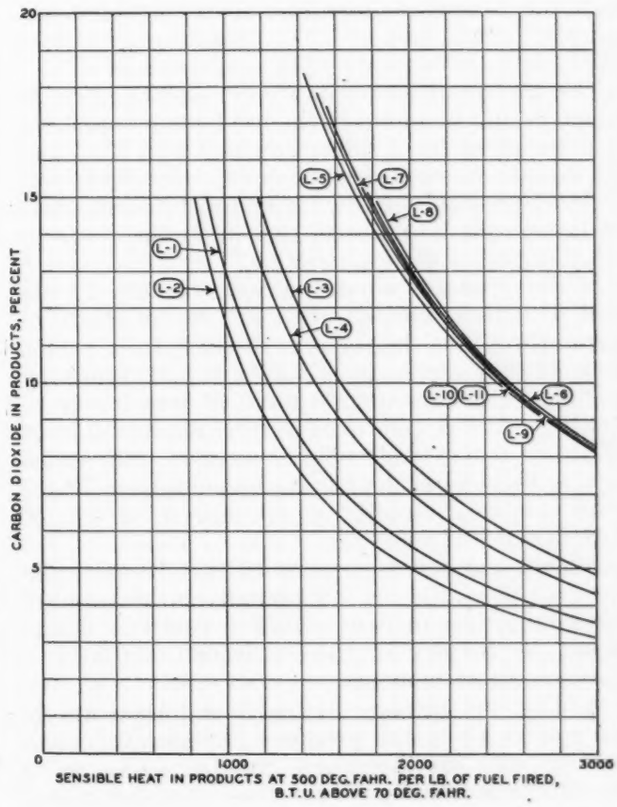
TYPICAL LIQUID FUELS

Curve numbers correspond with reference numbers in Tables I, II, III and IV









The nitrogen associated with this oxygen in atmospheric air is equal to 79/21 times the moles of oxygen, or $0.0720 \times 79/21 = 0.2709$ mole of nitrogen. Adding, we get $0.0720 + 0.2709 = 0.3429$ mole of dry air theoretically required per pound of Pittsburgh bituminous coal. With 70 per cent relative humidity at 70 fahr., there is 0.0176 mole of water vapor present with each mole of dry air, or $0.3429 \times 0.0176 = 0.0060$ mole of H_2O per lb. of fuel; see preceding article entitled "Humidity of Gaseous Mixtures."

The moles of products formed by complete combustion of one pound of fuel with this theoretical quality of air are also found by means of the chemical formulas in the preceding article. Thus, the moles of CO_2 are found by dividing the weight of carbon by 12, the moles of H_2O by dividing the weight of hydrogen by 2 and the moles of SO_2 by dividing the weight of sulphur by 32; or, $0.744/12 = 0.0620$ mole of CO_2 from the carbon C, $0.047/2 = 0.0235$ mole of H_2O from the hydrogen H and $0.010/32 = 0.0003$ mole of SO_2 from the sulphur S. The weight of nitrogen in the fuel is divided by 28 and the weight of moisture by 18 to get the corresponding moles of these substances in the products directly from the fuel; that is, $0.014/28 = 0.0005$ mole of N_2 and $0.034/18 = 0.0019$ mole of H_2O from the fuel. The moles of nitrogen and of moisture in the products from the air theoretically required for combustion, namely, 0.2709 mole of N_2 and 0.0060 mole of H_2O are placed in appropriate columns. Adding, we get the moles of each constituent in the products for complete combustion of one pound of Pittsburgh bituminous coal with the theoretical quantity of atmospheric air, namely, 0.0620 mole of CO_2, 0.0003 mole of SO_2, 0.2714 mole of N_2 and 0.0314 mole of H_2O.

The apparent percentage of carbon dioxide which would be found in the products by analysis, is determined by dividing the moles of CO_2 and SO_2 by the moles of dry products, or $0.0623/0.3337 = 18.67$ per cent. of CO_2 for complete combustion of Pittsburgh bituminous coal with the theoretical quantity of atmospheric air.

If the products are actually to contain 15 per cent of carbon dioxide, then the dry products of combustion must be equal to $0.0623/0.15 = 0.4153$ mole and the excess dry air to be supplied must be $0.4153 - 0.3337 = 0.0816$ mole, of which $0.79 \times 0.0816 = 0.0645$ mole will be nitrogen and $0.21 \times 0.0816 = 0.0171$ mole will be oxygen. The moisture in this excess dry air corresponding to 70 per cent. relative humidity at 70 fahr. is $0.0176 \times 0.0816 = 0.0014$ mole.

Adding the excess dry air to that theoretically required gives the dry air actually to be supplied for combustion, namely, $0.3429 + 0.0816 = 0.4245$ mole. In this dry air there is $0.0060 + 0.0014 = 0.0074$ mole of moisture.

Adding the nitrogen, oxygen and moisture in the excess air to the products for complete combustion with the theoretical quantity of air, gives the products actually produced as tabulated, namely, 0.0620 mole of CO_2, 0.0003 mole of SO_2, 0.3359 mole of N_2, 0.0171 mole of O_2 and 0.0328 mole of H_2O. These may be combined for sensible heat calculations as shown in Table V.

If the percentage of excess air is desired, it can be found by dividing the moles of excess dry air by the moles theoretically required, or $0.0816/0.3429 = 23.80$ per cent of excess air corresponding to 15 per cent CO_2.

The volume of air supplied for combustion and the volume of the products at any temperature and pressure are readily calculated by the aid of the table given in the article on the "Thermal Properties of Gaseous Mixtures" for the volume of one lb.-mole of any gas. Thus, at 500 fahr., the volume of one lb.-mole of any gas under normal atmospheric pressure is 700.8 cu. ft. Since 0.4319 mole of moist atmospheric air is supplied for combustion of one pound of coal, the volume of air supplied at 500 fahr. would be $700.8 \times 0.4319 = 302.7$ cu. ft. per pound of Pittsburgh coal. The corresponding amount of products per pound of coal is 0.4481 mole, which would have a volume of $700.8 \times 0.4481 = 314.0$ cu. ft. at 500 fahr. under one atmosphere pressure. If compressed to 10 atmospheres, the volume of the products would be $314.0/10 = 31.4$ cu. ft. per lb. of coal.

The weights of air supplied and of products produced may readily be found by multiplying the constituents by their molecular weights, remembering that the equivalent molecular weight of dry atmospheric air is 28.966. Thus,

$0.4245 \times 28.966 =$	12.296	lb. dry air,
$0.0074 \times 18.015 =$	0.133	lb. moisture
adding we get	12.429	lb. moist air supplied per lb. of Pittsburgh coal with 15 per cent CO_2; Also,
$0.0620 \times 44.000 =$	2.728	lb. CO_2,
$0.0003 \times 64.065 =$	0.019	lb. SO_2,
$0.3359 \times 28.16 =$	9.459	lb. N_2,
$0.0171 \times 32.000 =$	0.547	lb. O_2,
amounting to	12.753	lb. dry products;
$0.0328 \times 18.015 =$	0.591	lb. H_2O,
making	13.344	lb. moist products produced per lb. of Pittsburgh coal with 15 per cent CO_2.

The density of the products of combustion at any temperature is determined by dividing their weight by their volume as found above. At 500 fahr. under atmospheric pressure, for example, the density of the products is $13.344 / 314.0 = 0.0425$ lb. per cu. ft.

The sensible heat in the air supplied for combustion at any desired degree of preheat and the sensible heat in the products of combustion at any specified outlet temperature can readily be found

by means of the table of sensible heats in the article on "Thermal Changes in Gases." Thus, for the products at 500 fahr., we have

0.0623 ×	4766.4 =	296.9	B.t.u. for CO_2 and SO_2,
0.3530 ×	3496.5 =	1234.3	B.t.u. for N_2 and O_2
0.0328 ×	4178.0 =	137.0	B.t.u. for H_2O;
adding, we get		1668.2	B.t.u. per lb. of coal

For 70 fahr., we have

0.0623 ×	613.3 =	38.2	B.t.u. for CO_2 and SO_2,
0.3530 ×	487.2 =	172.0	B.t.u. for N_2 and O_2,
0.0328 ×	580.8 =	19.1	B.t.u. for H_2O;
adding, we get		229.3	B.t.u. per lb of coal.

1668.2 — 229.3 = 1438.9 B.t.u. sensible heat above 70 fahr. in products of Pittsburgh coal with 15 per cent CO_2.

The specific heat of the products of combustion is obtained by aid of the table of specific heats of gases in the article entitled, "The Thermal Properties of Gases." At 500 fahr., the heat required per pound of coal fired to change the temperature of the products one degree fahrenheit, is found as follows:

0.0623 ×	10.36 =	0.645	B.t.u. for CO_2 and SO_2,
0.3530 ×	7.04 =	2.485	B.t.u. for N_2 and O_2,
0.0328 ×	8.46 =	0.277	B.t.u. for H_2O;
adding, we get		3.407	B.t.u. per lb. of coal.

Since there are 13.344 lb. of products per lb. of coal, we have the specific heat at 500 fahr. to be 3.407 / 13.344 = 0.2553 B.t.u. per deg. fahr. per lb. of products.

All of the above calculations are based on complete combustion of the coal. Allowance for unburnt carbon can be made by substituting in Table V a value for C less than the carbon in the fuel fired by the amount of unburned carbon in the ashes, clinkers and flue dust. Allowance for the formation of carbon monoxide can also be made by dividing the net amount of carbon burned into two parts in the ratio of the percentages of carbon monoxide and carbon dioxide assumed in the products, an additional column being provided under products for CO.

Products of Typical Fuels

Applying the combustion calculations illustrated for Pittsburgh bituminous coal to all the typical solid and liquid fuels given in Table I., II., III., and IV., data were obtained for plotting the curves on pages 28 and 29 showing the variation with the percentage of carbon dioxide in the products of the weight of atmospheric air supplied for combustion, of the percentage of excess air, of the weight of products produced and of the sensible heat in these products at 500 fahr. above 70 fahr. In all cases, complete combustion of the fuel was assumed with no unburned carbon and no carbon monoxide in the products. The various curves are numbered in accordance with the reference numbers in Tables I to IV. Curves for pure carbon, designated by C, have been drawn for comparison.

These curves show the wide variations which occur in the air supplied for combustion and in the products produced with the various typical fuels as well as with different percentages of carbon dioxide in the products. These curves may be used in the solution of problems in which one of the typical fuels has been assumed. They may also be employed to check approximately the results of combustion calculations for any actual solid or liquid fuel approaching in composition one of these typical fuels.

Should any of the liquid fuels be atomized with steam, the weight of products at any given percentage of carbon dioxide would be increased, of course, by the amount of steam so employed per pound of fuel fired.

References

Among the many publications of the U. S. Bureau of Mines giving compositions and heating values of various fuels, Bulletin 22 may be mentioned in particular as containing data for coals from the various coal beds in the United States. Bulletin 22 was later supplemented by Bulletins 85, 123 and 193 on the same subject and by Technical Papers 269, 308, 344, 345, 347, 356, 365, 366, etc., containing data on coals from different states. The data on coals in the present article are based mainly on the paper entitled, "Burning Characteristics of Different Coals" by Kreisinger and Cross, published in A. S. M. E. Transactions for 1928.

U. S. Bureau of Mines Technical Paper 323C contains the United States Government specifications for liquid fuels. The Handbook of Oil Burning issued by the American Oil Burner Association contains the specifications for fuel oil adopted by that association. For Diesel fuel oil specifications, see the progress report issued by the A. S. M. E. Special Research Committee on this subject published in Mechanical Engineering for October, 1929.

Various waste fuels are discussed in U. S. Bureau of Mines Technical Paper 279. For a thorough discussion of City Wastes, see the several papers on this subject by Butterfield in Southern City for April, May and June, 1931.

The data on fuels in Volume II of the International Critical Tables are also of interest as well as that in various handbooks and textbooks on fuels and combustion. For heating value of corn, see article on this subject by the present author in Power for August 8, 1922.

It is desired to acknowledge the assistance of Dr. R. L. Brown, vice-president of the International Coal Carbonization Corporation, in selecting typical data for coke and coal tar products, and of Dr. E. E. Butterfield, chairman of the Committee on Refuse Disposal of the American Society of Municipal Engineers, in preparing the section on city wastes.

The Economics of Feedwater Regulation

By V. V. VEENSCHOTEN
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Northern Equipment Co., Erie, Pa.

COMBUSTION has always followed the policy of publishing material that will contribute to the more widespread use of equipment and apparatus which will either effect worthwhile savings or advance the standards of plant operation. Such material is presented in the accompanying article. While the advantages of automatic feedwater regulation are quite generally recognized, the many economic benefits which accompany its use are not fully appreciated. In discussing this aspect of feedwater regulation, the author cites a number of cases in which substantial savings have been recorded.

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IT is no longer necessary to point out the desirability of automatic feedwater regulation. It is now generally recognized by both designing and operating engineers. But probably only a few engineers actually realize what savings result from the use of boiler feedwater regulators. With engineers being forced to consider equipment on the basis of an investment which must return definite dividends, it might be well to consider feedwater regulators on that basis.

Feedwater regulators save labor. They increase boiler efficiency and decrease the cost of boiler maintenance. They increase the efficiency of feedwater heaters. They reduce pump maintenance costs. Let us examine some of these forms of savings.

The saving in labor is easily traced after the feedwater regulators are in service. Once the manual labor of tending the water is eliminated, it is no longer necessary to have a man specifically for operating the hand valves in the boiler feed lines. The fireman can easily supervise the water level without interference with his regular duties. In small plants where the fireman regularly tends the water, the time required for this part of his work can profitably be given to the supervision of his fires. The maintenance cost of a good feedwater regulator is so small as to be a negligible factor.

These statements have been confirmed many times by operators in power plants using feedwater regulators. One company reported one man easily taking care of the feed to 24 boilers, where with hand control three additional men had been required. These extra men had been needed 12 hours a day during the seven warmer months and 20 hours a day during the rest of the year. This meant that the feedwater regulators saved $9558.96 a year above all operating costs, a return of 284 per cent on the money invested in the equipment. In other words, the entire investment was repaid nearly three times each year.

Another plant reported that regulators made it possible to place four water-tenders per shift on more important work. This represented a saving of $28,000 a year, so that the regulator installation actually returned about 400 per cent a year on the investment. No attempt was made to estimate the savings in this same plant brought about by the elimination of much of the priming under heavy loads, resulting in drier steam and more even superheat.

Another form of savings effected by feedwater regulators lies in the increase in feedwater heater efficiency. This also is easily determined. Modern feedwater regulators which feed continuously as long as the boilers are under load keep the flow through the heater proportional to the steam supplied to it. This raises the temperature of the feedwater by cutting off the valleys on the temperature chart caused by irregular feeding. The charts, Figs. 1 and 2, show the average feedwater temperature raised 32 deg. fahr., this representing a 3 per cent saving in the coal burned. No other changes were made in the plant, so that the improvement was all directly traceable to the feedwater regulators. These charts, and this summary, do not take into account the water which might be wasted by intermittent operation of the heater. During periods of excessive demand, an excess of makeup is supplied which must be discharged during periods of decreased demand, thus losing the water as well as the heat units supplied to it.

The increase in boiler efficiency is more difficult to measure as it can only be determined by an accurate boiler test. Such tests have been made at various times. In one of the most comprehensive of these tests to come to the writer's attention, hand-feeding was compared with automatic feedwater regulation. In this case, an efficiency of 66.5 per cent was found with hand control, and

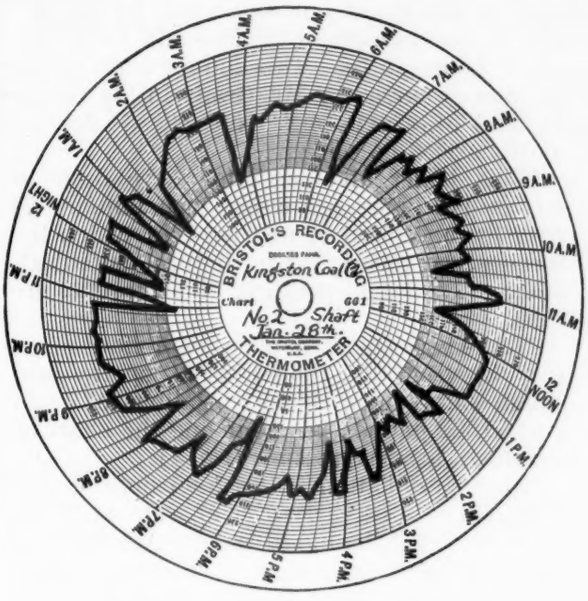

Fig. 1.—Feedwater temperature chart with hand control showing an average feedwater temperature of 178 deg. fahr. (Courtesy of Kingston Coal Company).

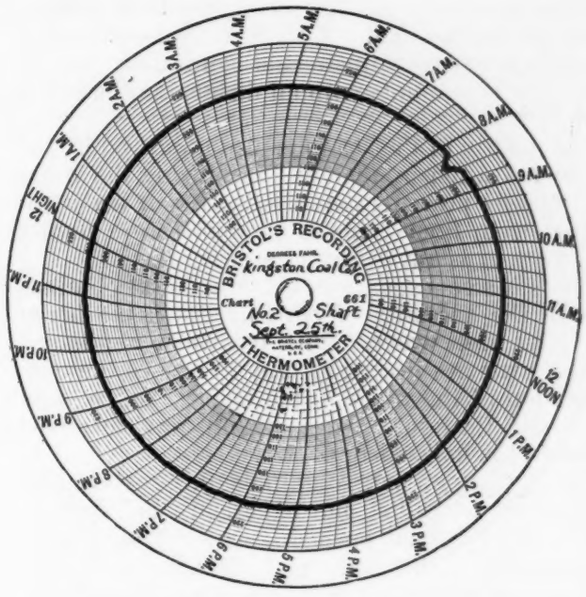

Fig. 2.—Feedwater temperature chart after installation of automatic regulation showing an average feedwater temperature of 210 deg. fahr. or an increase of 32 deg. (Courtesy of Kingston Coal Company).

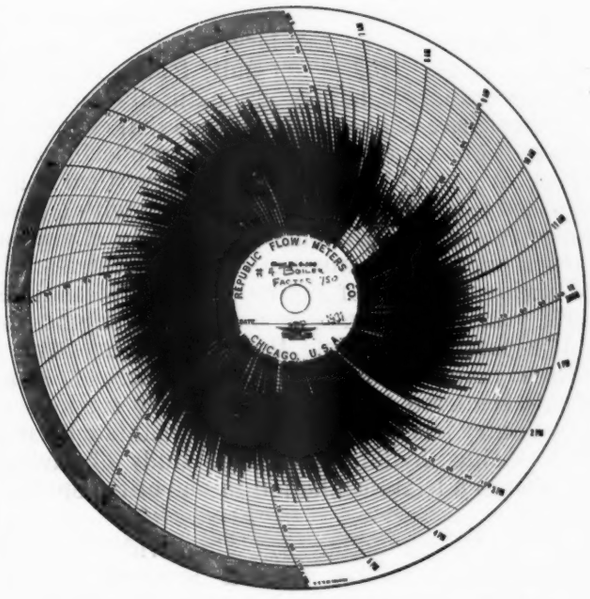

Fig. 3.—Steam flow chart for boiler No. 4, Masonite Corporation plant, Laurel, Miss. Note the momentary variations from 0 to 55,500 lb. per hr.

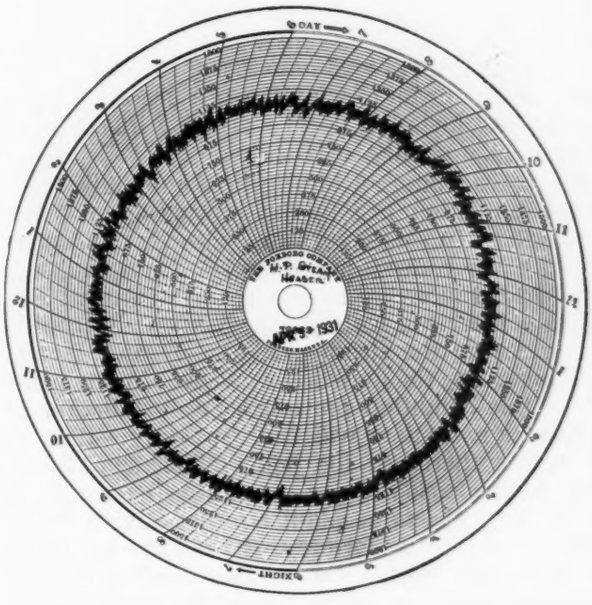

Fig. 4.—Steam header pressure chart for boiler No. 4 at the Masonite Corporation. Pressure fluctuates momentarily between 900 and 1125 lb.

this was increased to 73.2 per cent with automatic control. While this is a very great gain in efficiency and might not seem justified by the difference in methods of boiler feeding, no other change was made in the operating conditions and other tests have shown strikingly similar results.

The load on a boiler is greatly affected by a change in the rate of feedwater supply. A sudden increase in feed will absorb enough heat to reduce the quantity available for steam generation, forcing other boilers in the battery to supply the steam. This necessitates a change in the combustion rates of the different boilers and this is made at the expense of boiler efficiency.

Manual control of the boiler feed is always accompanied by these sudden changes. A watertender must see an appreciable change in level before adjustment of the feed valve seems necessary.

An attempt to bring the level back to the correct position results in the flow being changed suddenly and to great extent. A modern feedwater regulator makes these adjustments continually and in microscopic amounts without disturbing the boiler load.

The quality of the steam is also improved by the use of feedwater regulators. Stabilizing the water level largely prevents the introduction of water into the steam line. This is conducive to a higher and more constant degree of superheat.

There is also a saving in heat due to the elimination of the necessity of blowing down the boiler to relieve high water. With feedwater regulators, blow-downs are necessary only to reduce the concentration of the water in the boiler. The regulator holds the water level within predetermined limits in the boiler drum.

The saving in boiler maintenance cost is also difficult to determine, but experience has demonstrated the fact that burned boilers are almost invariably due to the failure of the human element rather than to the failure of an automatic control. In fact, one survey covering a 10-year period showed 85 per cent of all boiler accidents having been caused by human failures. Only 15 per cent of the accidents could be traced to failure of equipment. One plant reported that as soon as feedwater regulators were installed there was a noticeable reduction in tube renewals which they estimated conservatively as amounting to $1,000 each year. Other items of maintenance are also influenced. For instance, users report the life of gage glasses to be greatly increased.

One other economic advantage of automatic feedwater regulation lies in the prevention of wide fluctuations in steam pressure. Under hand control of boiler water input, there is often a tendency for the load to swing back and forth between different boilers in a battery, and this usually results in decreasing the steam pressure of some boilers and increasing the pressure of others. In one plant where this condition prevailed, the installation of feedwater regulators was conservatively estimated as having increased the boiler efficiency 1.5 per cent, saving $5365.50 per year in coal purchased. In addition, the same plant reported saving $6250 per year by placing former water-tenders in charge of other work which did not lend itself readily to automatic control. Thus the total annual saving effected by the regulators was $11,615.50. This paid for the regulator installation within three months.

In another plant operating five boilers, feedwater regulators were installed to overcome fluctuating loads. After the installation had been completed, it was found that the same load could be carried on four boilers, thus saving the operating cost of the fifth boiler.

The steady feed provided by automatic feedwater regulation also reduces the cost of pump maintenance, especially in the case of reciprocating pumps where the increased speed required for maximum loads reduces the life of packing, rods, pistons, valves, etc.

A recent statement on the value of feedwater regulators is of interest. It was made by Mr. E. G. Grady, steam engineer of the Masonite Corporation plant at Laurel, Miss. This unique high-pressure plant was discussed by Mr. Grady in the January, 1931, issue of COMBUSTION. In a letter to the editor of COMBUSTION, he said:

> "This boiler and regulator have been in service 146 hours per week since January 26 with the exception of one week in which the furnace was redesigned for natural gas installation. The total operating hours to date are 1410.
>
> "There are enclosed one steam flow chart (No. 3) from this boiler, 3820 square feet, which shows momentary variations of from 0 to 55,500 pounds per hour and the chart of the steam header pressure (No. 4).
>
> "Since installation it has been noticed that there has been no carry-over of water with the steam and that the life of the gage glasses has been increased 100 per cent. There are other operating advantages too numerous to mention."

Incidentally, the maximum water level variation observed on this boiler, according to a later statement by Mr. Grady, has been only five in., despite the severe fluctuations in load and pressure.

It has been said that feedwater regulators are more important for the larger boilers than for smaller units. This is not quite true. While the savings on larger boilers are naturally more impressive, there is plenty of evidence that economies effected on smaller boilers are proportionately great. A hospital operating a 50 hp. vertical boiler reported saving 300 lb. of coal per day with a feedwater regulator. The chief engineer in charge of power plants for a number of sugar centrals told of saving the cost of his regulators several times each year by eliminating damage to engines by water passing over into the steam lines. And a cheese manufacturer with a number of small plants scattered throughout the dairy sections of the country has equipped 16 boiler plants with regulators since making a detailed study of savings effected in a trial installation in one of the smallest plants.

Feedwater regulators pay big dividends. One prominent consulting engineer has said that no other piece of power plant equipment pays for itself as quickly through savings as does a feedwater regulator. The saving of labor, the increase in efficiency and the decrease in cost of maintenance commend them to the engineer seeking to reduce operating costs.

One thing must be borne in mind. A feedwater regulator will give these benefits only if it is designed and built to meet the actual operating conditions. It is a piece of equipment which must be made to measure for the individual job if satisfactory results are to be obtained. No feedwater regulator taken from stock can meet all conditions, nor can a stock regulator effect the economies which a correctly-designed regulator should give.

Handling Coal and Ashes at Longworth Steam Station

By H. V. SCHIEFER,

R. H. Beaumont Co., Phila.

Simplicity, dependableness of operation and low maintenance are the principal requisites of a coal and ash handling installation. These requirements are well met in the installation at the Longworth Steam Station. The author presents a detailed description of the operation of this installation and the equipment comprising it.

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THE coal and ash handling machinery installed in the new station of the Dayton Power and Light Company at Dayton, Ohio, is representative of the most modern trend in the use of this type of equipment.

The entire operation of coal elevating, distributing, storing and reclaiming is done with a minimum of machinery. All motors are located on the ground. Operation of the entire coal handling is controlled by one man.

A minimum of shutdowns is insured by using few moving parts, and making these few moving parts both heavy and easily renewable.

The station is located in the heart of the city so that ground space is limited. With the arrangement of machinery adopted, full use of the available property was made without impairing the operation in any way, in fact it was a help rather than a hindrance as it has resulted in all of the machinery being "bunched" making it easier for the oiler, inspector and operator.

The problem consisted of taking coal as received in railroad cars and either elevating it to overhead bunkers, or storing it on the ground, then reclaiming the stored coal and elevating to overhead bunkers.

In a steam station such as this there are times, particularly in summer, when the station is off the line probably for considerable periods. A sudden cold spell requires that the station must be in operation immediately. This means that the coal handling machinery will be idle for protracted periods, and then must operate without any preliminary attention. With the type of machinery in this station, there is practically nothing to deteriorate, all coal being handled in a skip bucket and tram car. These are simply steel "boxes" mounted on wheels. The single driving unit is a totally enclosed gear case immersed in oil.

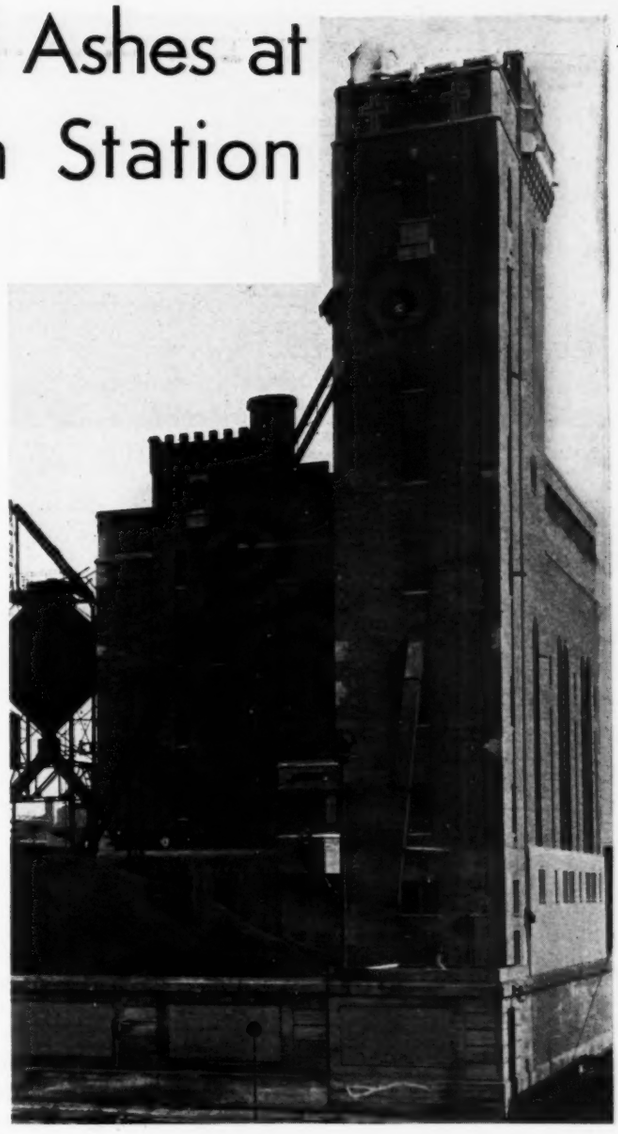

Fig. 1. View of Longworth Station showing ash bunker on left and skip hoist guides in foreground.

The coal handling machinery will elevate and store coal at a rate of 100 tons per hour. The ground storage capacity is about 7000 tons. Fig. 2 is a layout showing the coal and ash handling operations. Coal is brought to the plant in standard railroad cars, and dumped into a track hopper. Through a standard loader, coal is discharged to a fully automatic skip hoist, which elevates it to the top of the coal tower. From the skip, coal is transferred to a tram car for distribution in the overhead coal bunker.

When coal is to be stored on the ground it is elevated by the same skip, but instead of going to

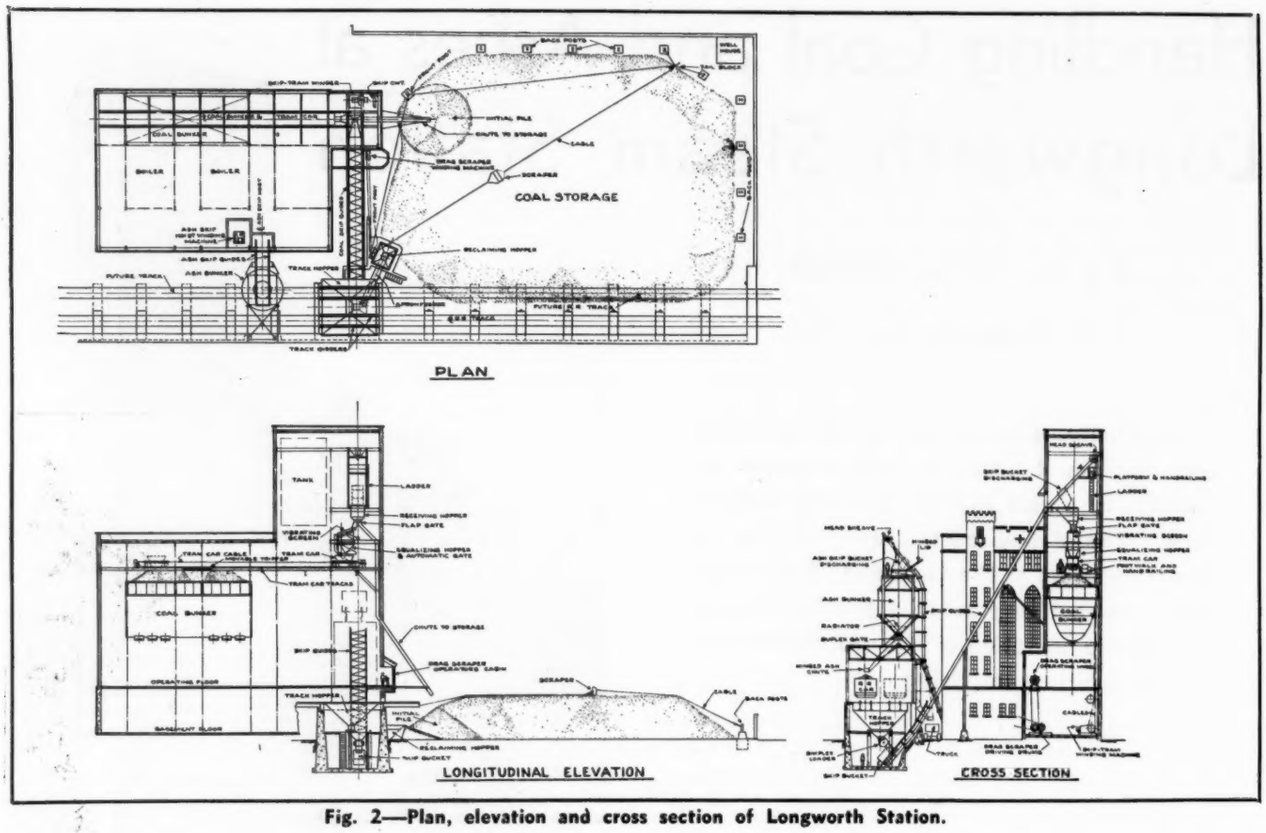

Fig. 2—Plan, elevation and cross section of Longworth Station.

the tram car, it is diverted through a chute to an initial pile on the ground where a cable drag scraper spreads it in a uniform pile. When reclaiming stored coal the cable drag scraper bucket is reversed, and coal is scraped into the track hopper and is then elevated and distributed by the above mentioned skip hoist and tram car.

With this arrangement, either crushed or lump coal can be stored on the ground. Coal for this plant must be bought in the open market. At the present time slack coal is the most economical but some time in the future it may be advantageous to buy lump or run-of-mine coal. This may be due to price changes, strikes, weather conditions, car shortages, etc. No crusher is installed now, but space is provided for it. In the event that crushed coal is not available or that lump coal should become cheaper, a crusher could be quickly and easily installed. The location of the coal crusher is very important in any plant where frozen coal is liable to be encountered, and especially where crushed coal is stored. The advantages of placing the crusher overhead are readily apparent. The usual deep concrete pit under the track hopper is thus eliminated and only a shallow pit is required, which lessens the cost of installation as the waterproofing of a deep pit is a serious problem. A locomotive must run over this pit, which places heavy loads on it so that the danger of cracking is always present. Deep pits usually require a sump pump to keep them dry. But probably most important of all is that with the crusher overhead there is no electrical motor or machinery in the pit where it is liable to be damp and dark. No motor or electrical equipment should ever be placed in a pit especially when it is below the local sewer level.

The skip hoist will handle either slack or lump coal. If the crusher were located in the track hopper pit it would be necessary to crush the lump coal before storing. In cold weather coal stored is almost sure to have frozen lumps in it, which would mean that all coal would have to be crushed twice and since this is a steam heating station, it is used mainly in cold weather. This means that practically all coal used would have to be crushed twice. With the arrangement used, having the crusher overhead, lump coal would be stored, the coal being by-passed around the crusher and stored as received.

For the present there is a single track for the receipt of coal (see Fig. 2). A second track is provided for. The present track is elevated to conform to the grade of the main line of the railroad. A single steel track hopper is placed under both the present and future tracks. This track hopper terminates in a single outlet to which is attached a simplex automatic loader.

This loader (Fig. 3) consists of a fixed chute or body bolted direct to the bottom of the hopper. It supports a pivoted undercut gate that has a covered nose chute.

The pivoted part of the loader is opened by the descending skip bucket coming in contact with and pulling down a spring hook attached to the loader nose. It is closed by the ascending skip bucket pushing it up to its closed position. The loader hook is of the spring draft friction type, which

equalizes the pull on the chute and prevents undue shock to either bucket or loader at the instant of contact. This hook is pivoted to the loader nose so that it will hang and swing freely. Pivoted loader sides are fitted with cast-iron counterweights. These counterweights are for balancing only. The gate is opened and closed by the skip bucket. The clear opening of the gate is 24 in. by 36 in.

The fixed chute side castings are provided with a latch which engages the loader nose when in the uppermost (closed) position, and holds it positively clear of the descending bucket.

Should the skip bucket fall by accident, no damage would be done to the loader, as the sudden impact with the opening hook would cause the latter to swing back out of engagement.

The operation of the skip hoist is fully automatic. A button is pressed. The skip ascends, stops and discharges its load, reverses, descends, opens the gate, receives its load, reverses, closes the gate and continues the cycle until stopped by the operator. The entire operation is effected by a traveling cam limit switch geared to the winding machine that is located in the basement of the boiler house. There is nothing in the track hopper pit. Hence no interruptions nor accidents can occur due to water or coal dust that is ever present in track hopper pits.

The skip hoist consists of a single, counterweighted bucket, running in conjunction with and synchronized with a horizontal tram car. The skip, winding-machine drum shaft is extended and has another drum mounted on it. This second drum operates the distributing tram car through a set of cables, so that the tram car makes a horizontal cycle corresponding to the inclined cycle of the skip hoist. These drums are of different diameters to provide for the different lengths of travel of skip and tram cars. The tram car drum is clutched to the drum shaft. When coal is being stored in the

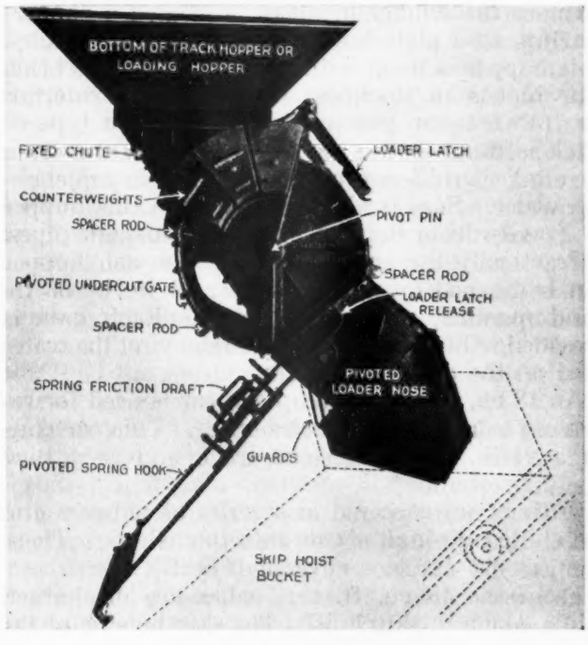

Fig. 3—Automatic loader.

Fig. 4—Drag scraper control room.

yard, the tram car is not used and is declutched.

The skip hoist winding machine is especially designed for heavy, continuous service under the severe operating conditions that a reversing skip hoist demands. It is of the spur-gear type. The drums are direct connected to the motor by a train of cut steel spur gears, which are fully enclosed by a cast iron housing, and run in oil. The machine is fitted with a shoe type magnetic brake, control equipment and slack cable switch. The entire operation of the machine is automatic and fool proof.

The tram car travels the full length of the overhead bunker each trip. It is provided with a bottom dump, two-leaved gate, the opening being parallel to the direction of travel. Each leaf of the gate is provided with a roller. At any point desired these rollers engage a tripper, which simply "splits" the gate open. This tripper is a double cam mounted on wheels, and is spotted by hand from the end of the runway. Due to the design of tripper and gate, and due also to the very slow speed of the tram car, there is no noise or jar in the operation. There seems to be less dust in this dropping of coal in "gobs" than is usual when discharging in a high velocity "stream."

The crusher room is located overhead and is a part of the distributing gallery. This room and gallery are entirely closed off, from the main boiler room.

The regular operation is that coal is discharged from the skip onto a vibrating screen. This screen removes any oversize material such as large lumps of coal, tramp iron or wood. From the screen, coal drops into a small equalizing hopper which is provided with a special type of gate. This gate is opened and closed by the tram car.

Directly over the stoker aisle there is a steel suspended bunker of approximately 1,000 tons capacity being 22 ft. 4 in. wide and 26 ft. deep. Steel spouts provided with cutoff gates are used for feeding coal to the stoker magazine.

When sending coal to storage a gate above the screen is thrown diverting the coal through a steel chute to an initial pile on the ground.

From the initial pile, coal is distributed in the area reserved for coal storage. This area is sur-

rounded by an ornamental concrete wall about 9 feet high, which effectually hides the coal pile from the passerby. It also prevents theft of coal. When piled about 20 ft. deep, about 7000 tons are accommodated.

Coal is stored by means of a cable drag scraper. This consists essentially of a steel bucket, which is dragged back and forth across the area. The bucket is so constructed that coal is moved in one direction only, the bucket automatically discharging at the end of its run and returning empty. A snatch block is moved around the field making the pile fan shaped. The cables are driven by a special two drum motor-driven winder located on the ground floor of the boiler house. The workman operates this winder through a system of levers from an operator's cabin located on the second floor of the boiler house. (See Fig. 4.) The

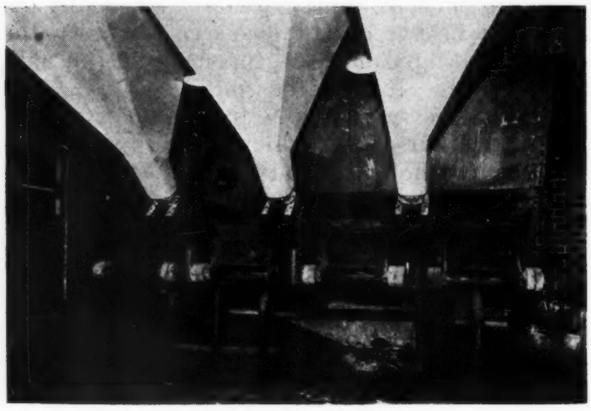

Fig. 5—Ash hoppers.

winder consists of a single continuous running motor attached to the two drums through a set of gears, brakes and clutches. When the scraper is traveling in one direction, one drum is clutched while the other is free and vice versa. The arrangement of levers is such that the operator cannot engage both clutches at the same time.

When it is desired to reclaim coal, it is necessary to simply reverse the hitches on the scraper bucket. Coal is then dragged to a reclaiming hopper. This hopper is located over and feeds into a short inclined conveyor that delivers the coal to the inclined skip hoist.

Stated briefly, the reasons for using a cable drag scraper were:—

First, *Economy.* It is the simplest system of coal storage yet developed. Coal is stored for insurance against shutdowns and should not be rehandled unless necessary. In order, therefore, to reduce carrying charges on idle equipment, the simplest and least expensive machine should be used for this purpose.

Second—*It reduces fire risk.* By spreading the coal evenly, so the the fine coal fills the interstices between the large lumps fire risks are greatly reduced. Coal should not be dropped onto a storage pile from a single point, so that it forms a cone or inclined surface down which lumps may roll, causing the coarse coal to separate from the fines. This is one of the principal causes of spontaneous combustion. This scraper system will attack possible fires in any part of the pile, digging down to the heart of the fire very quickly so that it can be uncovered and quenched.

Third—*Minimum dust.* Since this storage pile is adjacent to dwellings, flying dust would be very objectionable. This method creates less dust than any other system.

Fourth—No parts of the scraper show above the walls surrounding the pile.

Fifth—*Operation.* This system is operated by ordinary labor, thus eliminating any dependence on a high-priced operator, such as is required to operate a crane.

Sixth—*Maintenance.* The largest part of the investment is in steel and concrete, which have a very low depreciation value. When the machine is idle, the rope is wound on the drums, and the scraper stored under cover, the only parts exposed being the front and back posts.

Seventh—*Interest on investment.* The first cost of the equipment is lower than any other system. The skip hoist is necessary to unload and elevate coal, even though no ground storage is carried. This leaves only the driving drums, cables, bucket, posts and short conveyor to be charged against the ground storage, giving an extremely low cost per ton handled.

At present one boiler is installed, but coal handling equipment has been installed to take care of the ultimate boiler capacity.

Ash Disposal

There is a demand for ashes in this territory so that one of the principal features in the selection of ash handling equipment was to choose one that removed ashes to trucks or cars in a salable condition. Simplicity of design, low first cost, and low maintenance were also controlling factors.

Under the clinker grinders is located a copper-bearing, steel plate hopper of 500 cu. ft. capacity. This hopper is lined with hard-burned shale brick four inches in thickness laid in cement mortar. Due to abrasion, pressure and water this type of brick is much better than firebrick. Water from the clinker grinders provides the necessary quenching water. Soot is also gathered into this hopper by gravity from the flue chambers through pipes.

Practically the entire length of the ash hopper can be opened by means of four 24 in. by 36 in. hand-operated, pivoted ash gates. Each gate is provided with a water drain for removing the water used on the clinker grinders.

An 18 cu. ft. rotary dump ash car is used for removing ashes from the ash hopper. This car runs on a 24-in. gage industrial track and is pushed easily by one man.

Siftings are gathered in a series of hoppers and are chuted through a gate into the ash car. These hoppers are asbestos covered (Fig. 5).

From the 18 cu. ft. car, ashes are discharged into a 20 cu. ft. skip hoist. The skip hoist is of the

(*Continued on page 61*)

Natural Gas for Industrial Boiler Plants*

By
CHAS. M. ROGERS

Mr. Bending's article in July COMBUSTION on the use of natural gas in power plants, covered burner and furnace design and discussed combustion calculations based on gas from the Amarillo field, Texas. The present article considers briefly the economics of natural gas as a fuel for industrial boiler plants and describes a number of installations in which this fuel is being used in boiler furnaces designed for other methods of firing.

WHEN a price for industrial gas can be obtained which will make money for the gas company and which will break even or save money for the industrial plant then it can and should by all means be used. Usually when used for process work, ceramics, etc., the price paid can be more than for other fuels because of the many advantages of the gas fuel and the gain in quality and quantity of products, but boiler plants cannot as a rule pay more. It must be sold to them on a competitive basis with other fuels, and pipe lines in general must have this industrial business to exist. This gives the rate making department a heavy load to carry. Gas in large plants (which in itself is a lengthy subject) can in most cases be used on a "dump" basis to help out the pipe line load factor and at a price which should save money for the plant. In such cases it is necessary that these plants, and other large users not sold on a firm basis, have their boilers equipped with burners for combination gas and oil, or coal, or both, depending upon where located, so that other fuel than gas can be resorted to during periods of pipe line peaks. Examples of plants so equipped in this territory are the steam generating stations in New Orleans, Houston, Dallas, Little Rock and Memphis. Of the equipment in these boilers more will be said later.

There are in the United States, at the present writing, about 49,700 miles of natural gas transportation lines, not counting distribution systems, gathering lines, nor minor branch lines, ranging from 24 in. down, most of the major ones being constructed within the last few years. These lines carried last year for industrial, commercial and domestic purposes 2,000,000,000,000 cu. ft.

The rapid growth in the consumption of natural gas in the United States is shown graphically in the accompanying chart.

The distribution of the use of the natural gas consumed in the United States last year, together with that of the soft coal and fuel oil, is shown in the following tabulation:

	Coal %	Oil %	Gas %
Railroads	28	21	..
Coke Ovens	16	..	..
Steamships	2	21	..
Electric and Gas Utilities	9	8	7
Domestic	19	2	20
Refineries	..	15	6
Carbon Black	..	..	14
Iron and Steel Manufacturers	6	6	..
Industrial and General Manufacturers	20	23	20
Gas and Oil Fields and Natural Gasoline	..	4	33
	100	100	100

Out of the 63 billion kw-hr. generated by public utility plants by steam power last year, 7 billion were produced by natural gas, 3 billion by fuel oil, and 53 billion by coal. In 1920 there was used by utilities for generating purpose 24 billion cu. ft. of natural gas which increased to over 120 billion feet in 1930 or 500 per cent in ten years, this in face of the fact that generating station equipment has progressed in economy and size (thanks to private capital and initiative) so that the pounds of coal (or equivalent in oil and gas) per kw-hr. generated in 1930 was 1.62, whereas 11 years ago in 1919 it required double this amount, or 3.2 pounds per kw-hr.

There is no answer to the question "How much gas will I use per ton of coal?" except insofar as this question applies to a particular job. Then it can be answered very closely after particulars are ascertained.

If it were possible to apply a formula or rule for finding the quantity or price of gas which would be competitive with coal or oil in all types of boiler plants it could be similar to the form as plotted in Fig. 2.

These curves assume a natural gas of about 1000 B.t.u. per cu. ft. replacing the average steam or stoker coal sold in this territory and the average fuel oil sold along the Gulf Coast.

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These curves must be used only in general or for averages and not to be used for any one individual job. It must be imagined that the horizontal scale represents all types and sizes of boiler plants, beginning at the left with small industrial

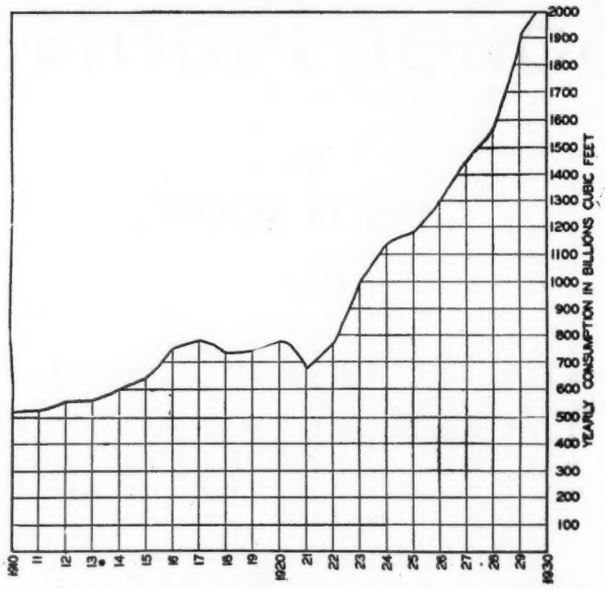

Fig. 1—Consumption of natural gas in the U. S. by years from 1910 to 1930.

plant boilers, hand fired, poorly operated, with high labor cost per ton of coal, and with poor efficiency as usual. The plants get larger and better and more modern until the last word in boiler room equipment is reached at the extreme right.

These values for gas were not arrived at in a theoretical manner but from empirical information gained from experience in converting numerous plants of all sizes and descriptions in this section of the country.

A brief explanation for the competitive gas price being low for the modern boiler room and high for the others will suffice to explain the curves. The contributing factors which make the high equivalent gas prices on the left of the chart are principally: (a) high labor cost per ton of coal in small plants, (b) higher efficiency with gas due to

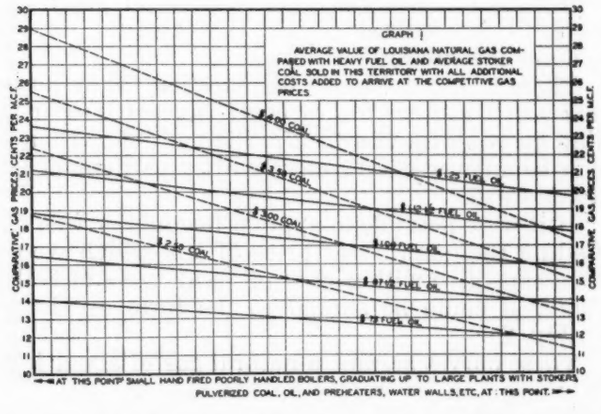
GRAPH 1
AVERAGE VALUE OF LOUISIANA NATURAL GAS COMPARED WITH HEAVY FUEL OIL AND AVERAGE STOKER COAL SOLD IN THIS TERRITORY WITH ALL ADDITIONAL COSTS ADDED TO ARRIVE AT THE COMPETITIVE GAS PRICES
COMPARATIVE GAS PRICES, CENTS PER M.C.F.
$4.00 COAL
$3.50 COAL
$3.00 COAL
$2.50 COAL
$1.25 FUEL OIL
$1.10 FUEL OIL
$1.00 FUEL OIL
$.875 FUEL OIL
$.75 FUEL OIL
AT THIS POINT SMALL HAND FIRED POORLY HANDLED BOILERS, GRADUATING UP TO LARGE PLANTS WITH STOKERS, PULVERIZED COAL, OIL, AND PREHEATERS, WATER WALLS, ETC., AT THIS POINT.

Fig. 2.—Relative values of Louisiana natural gas compared with heavy fuel oil and average stoker coal.

clean boilers, automatic control, less excess air, etc., (c) the usual small plant cannot purchase good coal in small quantities at the comparative prices shown. Thus, in a large modern plant gas would be worth 13c against $3.00 coal, whereas against this same coal in a small poorly operated plant the gas could be worth 20c.

These curves do not of course apply in exceptional cases where the above savings cannot be made. Competitive conversion ratios bear little relation to the f.o.b. cost of coal and oil. To these costs must be added the cost of unloading, storing, preparing, firing, maintaining equipment, power for operation, cleaning boilers, etc. It is these charges plus the difference in overall efficiencies in favor of gas that makes the lines slanting and

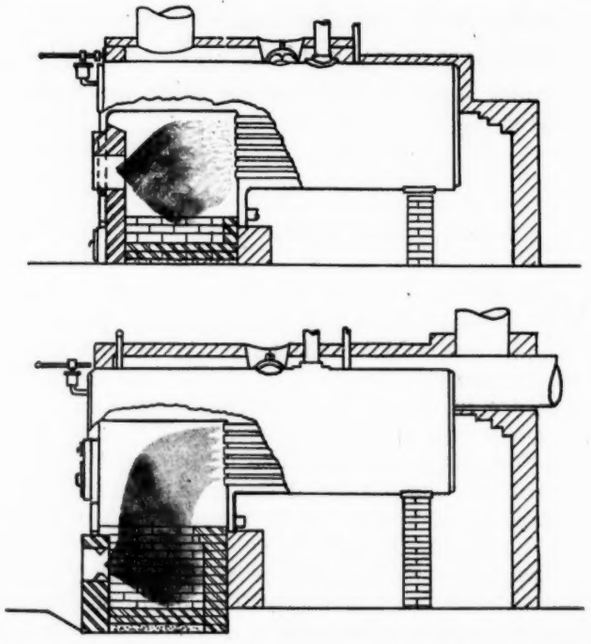

Fig. 3—Methods of installing gas burners in brick-set updraft fire tube boilers. The lower drawing shows the proper arrangement.

the competitive prices variable and rise approaching the small plant. It is not within the scope of this paper nor will time permit an elaborate analysis of these comparisons nor a discussion of the efficiencies obtained with the three fuels in the different plants referred to.

A few comparisons with actual experience in small boiler plants will show the gas prices read from the curves at the left side of chart to be correct when all charges are considered; also at the extreme right, when considering that higher efficiency can be obtained with coal or oil than with gas in such plants, plus comparing the actual results in some of the large modern plants, it will be found that the competitive gas prices shown by curves are likewise about correct.

Two practical reasons for this variation in efficiency between gas and coal and oil are: (a) the furnace temperature is lower with gas, and (b) co-mingling of air and gas for rapid combustion is accomplished so easily that it is practical to run

with 5 to 10 per cent excess air without incomplete combustion or injury to furnace, almost regardless of the size of the plant. If this were attempted with coal or oil in these furnaces, the temperature would be too high and incomplete combustion would result, except, per se, in the case of large furnaces on pulverized coal or oil where the water-walls and furnace volume permit operation with a minimum of excess air resulting in higher efficiency than with gas. Such plants however are rare compared with the total with which we deal.

Some illustrations may now serve to better illustrate both usual and special problems encountered daily in converting both the boiler plants and the owners to successful gas users.

Typical of a large percentage of the small boilers in this territory are the illustrations shown in Figs. 3 and 4.

These boilers are often placed in basements having water-proofed floors. A common fault is to use the standard setting on these boilers which means that there is not room to put proper insulation and firebrick over the ash pit floor and still have space above it for the gas burner. The upper drawing in Fig. 3 is a very common setting and shows that the burner must be placed in the firing door which is not good practice. For boilers of this size the floor can be properly protected with one

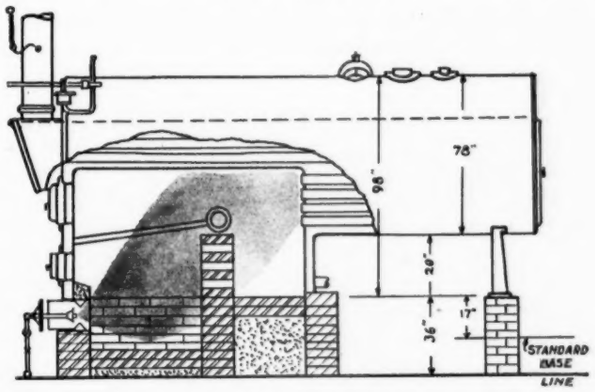

Fig. 4—Gas burner installation in portable down draft type boiler.

layer of insulating brick and two layers of firebrick or equivalent, but this is the minimum. The lower drawing in Fig. 3 shows the correct setting for boiler, furnace, and gas or oil burner.

Fig. 5 shows a cross section of an ideal conversion job. These boilers were equipped with Roney stokers set in quasi Dutch Ovens with flat arches before being converted to gas. To get combustion at the right point and also to prevent the gas flame from burning the back end of the flat arches, a front wall to hold the burners was built midway into the furnace as shown, this and the building of the bridge wall being the only changes required. The broken line shows the former grate line. Three burners were placed in each furnace so that one, two or three can be used, with correct heat distribution, dependent upon the variable seasonable load. Metal wind-box fronts were set flush with the old furnace fronts which were faced with enamelled brick to present a neat appearance. It does not hurt the gas company to make the job good looking. A Mason Regulator, actuated by steam pressure, automatically controls the breeching

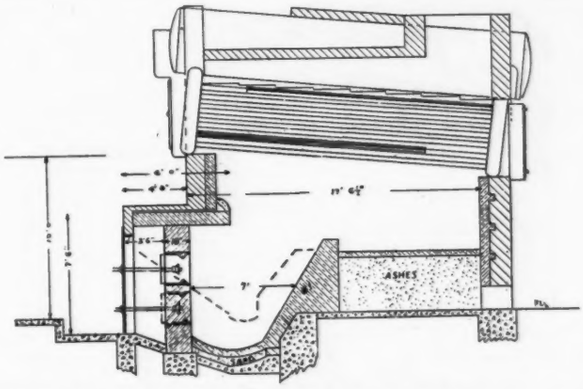

Fig. 5—Gas burners installed in box header boiler setting from which stokers have been removed.

dampers in unison with the McAlear gas control valve maintaining absolutely even steam pressure with less than 10 per cent excess air regardless of load.

We all come across industries having a refuse or by-product of some form to either save or destroy by using it for fuel. In many cases there is either too much of the refuse for fuel requirements at times or insufficient at other times. In most cases the grates or stokers must remain installed which presents an untenable situation with respect to a proper gas combination job. If the by-product is liquid the surmounting is easy, but for shavings, saw dust, boxes, slabs, etc., complications enter. Each case usually must be dealt with according to local conditions. Fig. 6 shows one way of providing means for hand-firing refuse on one side of furnace with capacity in gas burners on the other side to make up the fuel deficit or to carry the entire load when necessary. The steam pressure functioning through a gas fuel boiler governor provides gas as required to keep steam constant regardless of quantity of refuse fired. This is not the best for economy's sake but similar installa-

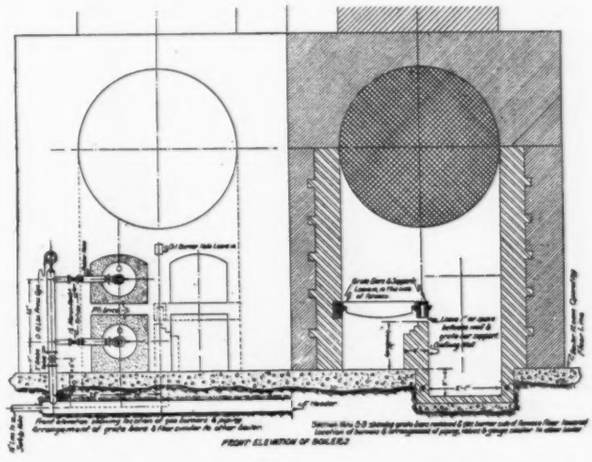

Fig. 6—Setting of H.R.T. boilers for combination gas, oil or refuse firing.

tions are used by two national manufacturers in various sections of the country.

A modern and better designed refuse and gas job is shown in the cross section of B & W boilers

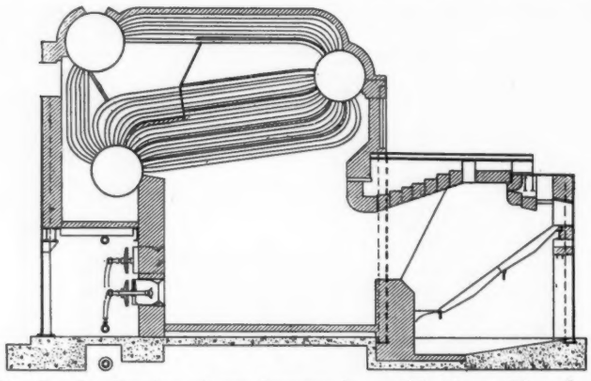

Fig. 7—Application of gas burners in combination with refuse burning stokers.

Fig. 7, with Hofft refuse stokers in the fronts and high pressure gas burners in the rear walls sufficient to handle any load on the boilers from 10 per cent to 300 per cent rating. This job has been working very successfully for over two years. The steam pressure controls the gas to the burner header through a Fulton Gas Fuel Boiler Governor. At times there is refuse to carry the entire load and again there is none—the gas automatically makes up for the deficit and maintains constant steam pressure.

The rights of the prospective industrial gas user to have his mechanical stokers remain installed for emergency are inviolable. We welcome the auxiliary equipment in the fuel oil burning sections but in coal burning territories it is a thorn in our side. As for leaving stokers installed to prevent shutting down the plant in case of a break in the pipe line there is no sound reasoning. The break would be repaired or service otherwise restored before stokers could be uncovered and put

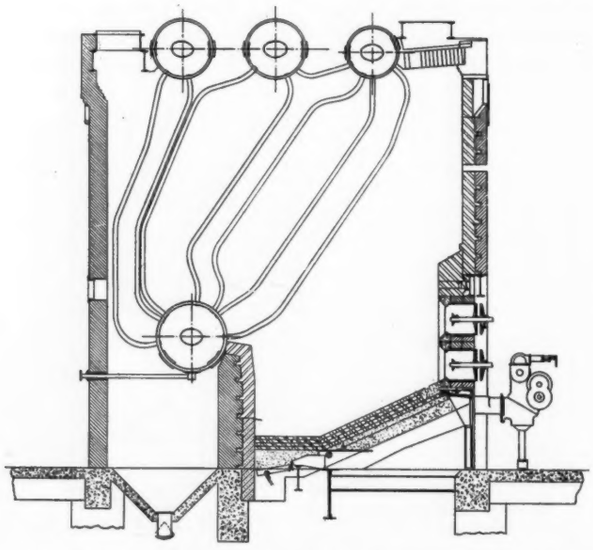

Fig. 8—Gas burners installed under stoker fired boiler without removing stokers.

in service. There are, however, two sound reasons why stokers along with coal and ash handling equipment should be left installed, which reasons are in favor of the customer and not the gas company. First, coal handling and firing equipment would have to be amortized. Second, the customer has either a real or imaginary reason for thinking he will get a better price on gas if his other fuel equipment remains installed ready for operation during the life of, or at the expiration of his gas contract.

Fig. 8 is typical of underfeed stoker jobs prevalent in this territory. This drawing shows one where the stokers remained installed for one of the above reasons. The stokers are painted with No-ox-id and levelled off with filter-cel or ashes and covered with firebrick and the burners placed above. With this type of burner, where flame and heat travel down as well as up and sideways, there is no loss in efficiency, no diminution of capacity except insofar as the space occupied by the stokers could be used for combustion space if needed for higher ratings.

Fig. 9 shows typical boiler settings for this section where the underfeed stokers have been removed and combination gas and mechanical oil burners are installed. A slab of concrete is put over the air ducts and ash dump and protected with

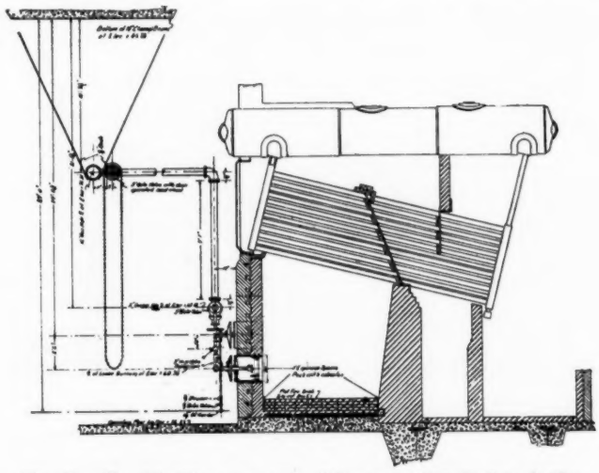

Fig. 9—Combination gas and oil burners installed in boiler setting from which stokers have been removed.

Sil-o-cel and firebrick. This plant has no water-walls nor air heaters. The average combined efficiency is 79 per cent. The average CO_2 is 10.5 per cent. The load fluctuates abruptly from 125 to 250 per cent rating. For several hours each day the cubical contents of combustion space per boiler horse power developed is 0.6 cu. ft. At this rating the heat liberation is about 56,000 B.t.u. per cu. ft. and without any injurious effect. With short flame burners this heat liberation can easily be attained, and, with forced draft this can readily be increased to above 65,000 B.t.u. per cu. ft.

Fig. 10 is an illustration of a conversion job where the stoker fans and extra combustion space provided by the removal of the stokers permit carrying almost double the load per boiler on gas that

is possible on coal. The stoker air ducts are filled with cinders to protect foundations and covered with a refractory floor on top. Practically doubling the combustion space and diverting the fan air to the gas burner wind-boxes for forced draft about doubled the capacity of the boilers, resulting in a very economical layout with a very moderate installation cost.

Fig. 11 is a cross-section of some boilers in a New Orleans plant which were set for oil or pulverized coal burning. The operating results on natural gas are excellent. On account of insufficient space for sufficient burner capacity between the mud-drum and the operating floor it was neces-

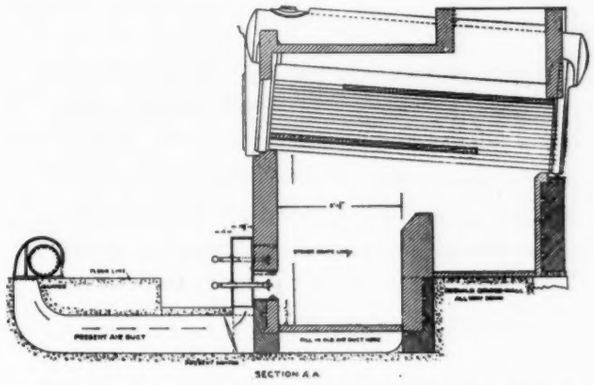

Fig. 10—Forced draft gas burners replacing forced draft underfeed stokers.

sary to crowd the burners in and keep the furnace floor a minimum thickness. To protect the concrete and preserve the furnace floor, the latter is built of hollow tile, Sil-o-cel, and a refractory top. The natural draft dampers in the wind-boxes are set to pull the proper amount of air through the hollow tile to keep the floor slab cool, which air is necessarily heated when entering the wind-boxes and is used for combustion. These burners can be switched to fuel oil without previous notice and without making or breaking any steam, oil, or gas connections.

Fig. 12 is a cross-section of another New Orleans boiler room where for local reasons, the owner desired an air cooled floor. He is proud of his operating results and his average CO_2 of 11 per cent, and became a good silent salesman for the gas company. As shown on drawing the furnace floor is built on pipes with supporting walls in the center and at the side of furnace. The natural draft pulls the required amount of air for cooling purposes through a damper box on each side of the furnace at the bridgewall and thence under the furnace floor into its respective wind-box where it is used for combustion. As the load is steady, the air, when once set, does not require regulation.

One of the larger and more efficient users of natural gas in generating stations is the Sterlington Plant of the Louisiana Power and Light Company. On account of its proximity to the gas field, this boiler room needs no standby fuel, water-walls, economizers, nor air preheaters. These boilers use 40,000,000 cu. ft. gas daily and frequently carry over 650 per cent rating.

Again, when we convert the industrial plant to use natural gas for fuel it should be competitive in price and profitable to the gas company. There

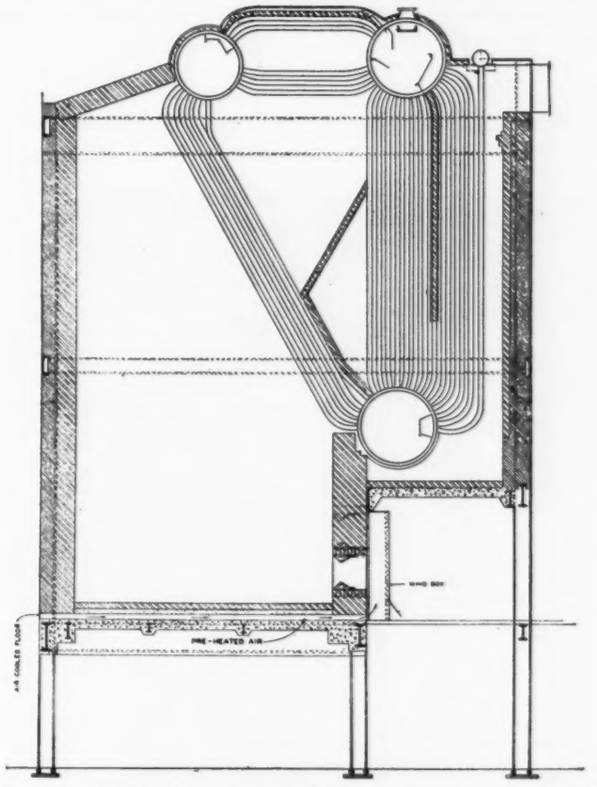

Fig. 11—Application of combination oil and gas burners arranged for firing through rear wall setting.

is a happy hunting ground some place between them where the welfare of the industrial customer and the financial prosperity of the utility merge and lose their identity. This is the point we should seek. Many boiler rooms need lots of soap, water, and paint in addition to natural gas, to change them from an inferno to a paradise. We should make the industrial installation clean, convenient, efficient, dependable, and thus contribute to the establishment of cordial and friendly relations with the customer upon whom depends much of the success of the public utility.

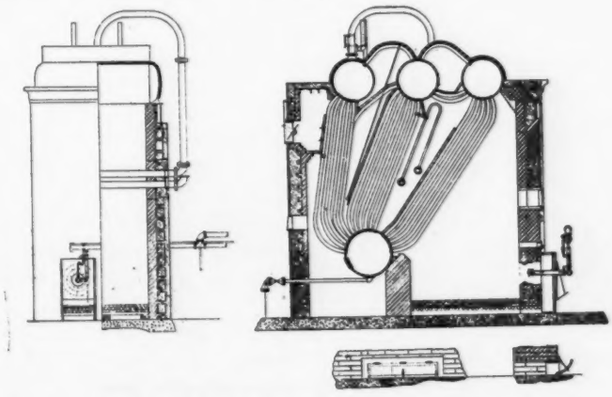

Fig. 12—Wind-box type combination oil and gas burner used in conjunction with air-cooled floor.

National Electrification in Great Britain

By DAVID BROWNLIE
LONDON

Every year is showing definite progress in the carrying forward of Great Britain's program for national electrification. Mr. Brownlie discusses some of the interesting phases of this work, and, in so doing, describes the new Portishead Station at Bristol and the area it serves, as typifying the general trends of the electrification program.

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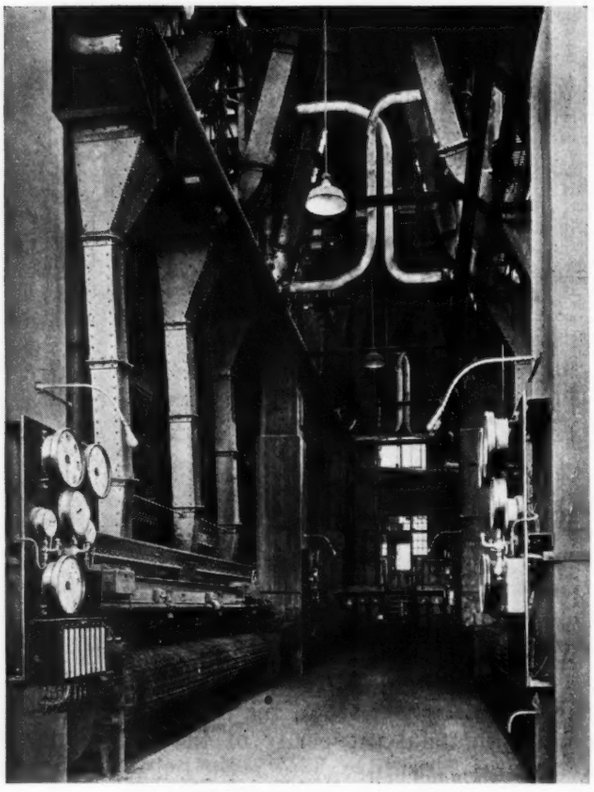


Partial view of boiler room at Portishead Station.

THERE has recently been published the "Weir" Report which in general recommends the electrification of the whole of the railways in Great Britain, totalling 49,000 miles, at a cost which would probably exceed $1,600,000,000, including $400,000,000 for new power stations. Whether the scheme will be carried out, wholly or in part, remains to be seen, but it is significant of the change now in progress in British industrial life, represented by the increasing use of electricity and the development of national electrification.

At the present time Great Britain has an annual output of about 11,000,000,000 kw-hr. not including, of course, the output of a very large number of private power plants.

However, the sale of electricity by public supply companies is increasing rapidly as shown by the accompanying figures for the output since 1924 as given in the Official Returns of the Electricity Commissioners.

Here then it is seen that in the 7 years 1924-1930 the production has increased from roughly 6,000,000,000 kw-hr. to 11,000,000,000 kw-hr. Also according to the latest figures the Central Electricity Board has placed contracts to the extent of $100,000,000 while an expenditure of about $25,000,000 has already been sanctioned for the change of frequency. Altogether about $250,000,000 will be spent in the immediate future on national electrification, quite apart from railways. Many important new power stations are now also in course of erection or enlargement in Great Britain, some of which have already been described in these columns by the present writer.

Annual Production of Electricity by Public Supply Companies in Great Britain, Expressed per Quarter, in Million kw-hr.

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Total
1924	1,664	1,347	1,331	1,752	6,094
1925	1,798	1,430	1,453	1,984	6,665
1926	1,992	1,459	1,458	2,131	7,040
1927	2,200	1,760	1,814	2,460	8,234
1928	2,472	1,994	1,929	2,678	9,073
1929	2,844	2,254	2,193	3,003	10,294
1930	3,031	2,390	2,341	3,152	10,914
1931	3,185	....	....	....	....

Naturally these developments have resulted in a great advance in the technique of steam generation and Great Britain to a more or less degree resembles the United States, Germany, France, Belgium, Holland, and other countries as regards a

pronounced tendency toward increase in size of boilers, steam pressures and temperatures of superheat, and more scientific methods both as regards pulverized fuel firing or mechanical stoking.

Essentially today what may be termed first-class practice in British power stations is boilers of from 100,000 to 250,000 lb. evaporation per hr., 450 to 650 lb. steam pressure, and 800 to 850 deg. fahr. superheated steam temperature. As regards methods of firing, the whole situation is in the melting pot again. There is, for example, no very well defined, general opinion as to whether pulverized fuel firing or mechanical stoking is the best. If anything pulverized fuel has not maintained its position so well during the past 12 months, while the unit system is growing in favor at a moderate rate at the expense of the bin-and-feeder system. But in the field of mechanical stoking the traveling grate stoker still remains supreme as against the multiple retort stoker, although the latter continues to be installed. These tendencies it will be noted are, in most respects, different from those of the United States. In Great Britain, the individual boilers are much smaller and less use is made of the forged drum, although such construction is being used at such notable plants as Bradford Corporation, the new Ford Works at Dagenham, and Synthetic Ammonia and Nitrates, Ltd., Billingham. Superheat temperatures in the newer plants are on the average higher than in American stations.

In the field of pulverized fuel firing there has not so far been the same landslide to the unit pulverizer at the expense of the bin-and-feeder system that seems to have occurred in the United States, while pulverized fuel firing by both methods has not progressed to the same extent, partly because of the higher ash content of British coals and also perhaps because the technique of the traveling grate stoker is very advanced in Great Britain. There also seems to be a general tendency to eliminate feedwater economizers and use air preheating only.

The fact that any one system of fuel firing has not a predominating lead in great Britain is well exemplified in the latest stations. For the 150,000 kw. extensions at Barking, London, traveling grate stokers are being installed for 8 boilers of 256,000 lb. normal evaporation per hr., 625 lb. pressure and 800 deg. fahr. superheated steam temperature. At "Dunston B," Newcastle, there will be 12 boilers each of about 150,000 lb. evaporation per hour for 625 lb. pressure and 825 deg. fahr. superheated steam, eight of which are to have traveling grate stokers, while the other four are being equipped with unit pulverizers.

There is also some tendency in Europe to adopt unit pulverized fuel firing as supplementary to traveling grate stokers. At Clarence Dock, Liverpool, now in course of construction, 4 boilers of 160,000 lb. normal evaporation at 450 lb. and 750 deg. fahr. steam temperature, to be raised to 825 deg. fahr., have traveling grate stokers with extremely large combustion chambers and auxiliary unit pulverizer equipment to take the peak loads. Dr. W. Lulofs of Amsterdam, where the new station is operating on these lines, has long been a prominent advocate of this system. The Kirkstall

The Portishead Power Station at Bristol.

Station, Leeds, however, with three boilers of 160,000 lb. evaporation per hr. is equipped with pulverized fuel on the bin-and-feeder system, like part of the Hams Hall Station, Birmingham, and Leicester, Derby, and Brimsdown, London.

The overall thermal efficiency of British stations is also rising and some typical figures for prominent plants, taken from the Electricity Commissioner's Reports are as follows:—

Thermal Efficiency of Leading British Power Stations with Coal Consumption in Lb. Per Kw-Hr.

	Fuel Consumption lb. per kw-hr.	Thermal Efficiency
North Tees	1.28	22.83
Barton, Manchester	1.33	22.10
Ferrybridge, Yorkshire	1.37	21.31
Deptford West. (London Power Co.).	1.39	22.14
Padiham, Lancashire	1.39	20.50
South Wales E.P.D. Co. Upper Boat	1.43	18.49
Hayle, Cornwall	1.44	17.18
Lister Drive No. 3 Liverpool	1.48	20.30
Barking, County of London E.S. Co.	1.50	22.02
Portishead, Bristol	1.53	18.20
Mersey Power Co., Percival Lane	1.54	18.21
Maidstone, Kent	1.54	17.80
Spondon, Derbyshire	1.57	21.14
Aberdeen Corporation	1.57	18.63
Agecroft, Salford	1.58	18.81
Hams Hall, Birmingham	1.60	19.83
Deptford East (London Power Co.)	1.60	19.23

Since the publication of these figures, however, the new Kearsley Station near Manchester is stated to be operating at 1.18 lb. of coal per kw-hr., full details being not yet available.

For the purposes of National Electrification, Great Britain is divided into seven areas and, as typical of the situation, reference will be made to the new Portishead Station of the Bristol Corporation and the southwestern area, that is southwest England and South Wales. The latter covers 17,234 sq. mi. with a population of 6,085,500, and includes such important towns as Bristol, Bath, Southampton, Plymouth, Falmouth, Cardiff, Newport, Swansea, Stroud, Frome and Swindon, with the extensive South Wales coal fields, the China clay industry of Cornwall and Devon, and the tin mines of West Cornwall.

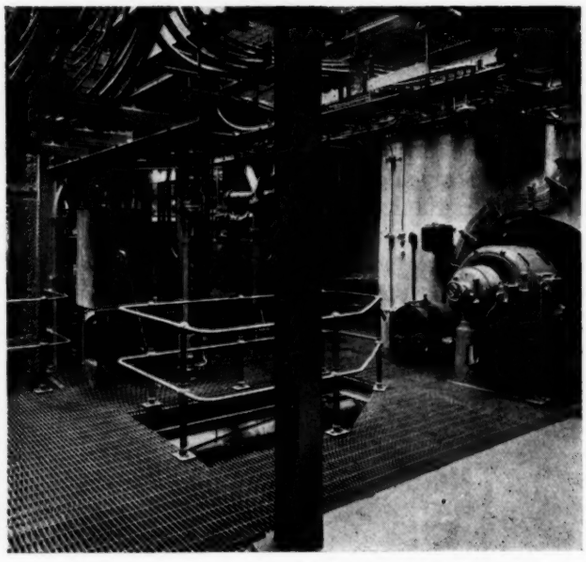
Under this national scheme, six existing power stations are to be operated, at Cardiff, Hayle, (Cornwall), Newport, Portishead (Bristol), Southampton, and Upper Boat, (South Wales), with suitable extensions as required, all linked up to the overhead transmission lines. Also two new stations will be built, one near Southampton and one in South Wales, and many small stations are to be scrapped.

The new Portishead station of the Bristol Corporation, at present 40,000 kw. and designed for 340,000 kw., is typical of the average good conditions of power station practice of several years ago, especially as regards safe and steady working before super-pressures were standard practice.

To American engineers also Bristol is of special interest if only because in the year 1497 John Cabot, a citizen of the town, although of Genoese origin, with his son, Sebastian, set sail and discovered North America. This feat is still recorded by a tablet on the old bridge in the middle of Bristol, to which his vessel was anchored.

Further, it is interesting to note that the first ship built for regular steamship service between Great Britain and the United States was the "Great Western," launched at Bristol, which sailed for New York on April 8, 1838, the voyage lasting 15 days and 10 hours.

In 1883, the Bristol Corporation obtained statutory powers to establish an electricity undertaking, but this was not actually commenced until 1892, with a very small station at Temple Back, carried out under the supervision of the present Chief Engineer and General Manager of the Bristol Corporation Electricity Department, Mr. H. Faraday Proctor.



Circulating water pump pit at Portishead Station.

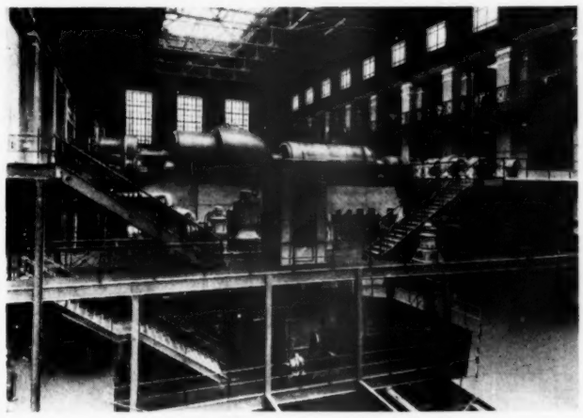
It is interesting to note that this first power station at Temple Back comprised two 52 kw. d.c. generators, two 88 kw. a.c. sets, and two 210 kw. a.c. Williams-Siemens sets. The consulting engineer was W. H. Preece, since famous for his pioneer work in wireless. Eventually the station at Temple Back, and also another station at Feeder Road, reached a capacity of 49,540 kw.

In 1924, it was recognized, however, that these two stations could not be extended to cope with the increasing load, which it is calculated will reach about 160,000 kw. by the year 1938 for the town alone. Consequently the present new Portishead generating station was erected on a site of 23 acres on the banks of the River Severn, with unlimited cooling water and adjoining the G. W. R. Company's sidings, which supply the Portishead Docks.

The station is divided into four main sections, comprising boiler house, turbine house, low tension switch house and high tension switch house, which latter is an entirely separate building, the whole equipment being built in tiers down a hillside, the boiler house firing floor for example be-

ing 61 ft. above ordnance datum and the turbine room floor 50 ft.

The present boiler plant consists of four Vickers straight-tube boilers, with a normal evaporating capacity of 80,000 lb. per hr. each, operating at a pressure of 325 lb. per sq. in. and a superheated



Turbine room at Portishead.

steam temperature of 725 deg. fahr., with a maximum capacity of 100,000 lb. evaporation per hr. Each boiler is also an entirely separate unit, comprising integral superheater and a superimposed steel tube economizer of the header type, and is fired by one 24-ft. wide Illinois chain grate stoker with a forced and induced draft fan of Sirocco make.

The induced draft plant is housed on the fan floor over each boiler, and incorporates also the Davidson grit arrester located in the breeching of the chimney the latter being of the steel type, 100 ft. effective height and 7 ft. 6 in. dia. The feedwater supply pipe is in duplicate, one steam turbine driven and two electrically driven centrifugal pumps being installed, with interconnecting pipes so that either feed main can serve any or all of the boilers. Further, the piping is so arranged that in the event of future extensions one boiler feed pump can be isolated entirely for testing purposes without interfering with the natural operation of the rest of the plant.

Complete control equipment is provided, with CO_2 indicators, steam pressure indicators, and draft gages grouped on instrument boards adjacent to each boiler, while in a central control room at the turbine end of the firing aisle are grouped steam flow recorders, integrating and summation watt meters, CO_2 indicators and electrically-actuated distance thermometers.

The generating plant consists of two Metropolitan-Vickers 2-cylinder impulse type turbo-alternators, each of 20,550 kw. maximum continuous rating, operating with steam at 300 lb. per sq. in. pressure and 725 deg. fahr. at the stop valve, the high-pressure cylinder being of cast steel containing 20 expansion stages, with diaphragms built up of mild steel with machined nozzles. The low-pressure cylinder is of the divided-flow type, the steam after expanding through two stages being divided, one part being diverted to the second stage of the cylinder from which it proceeds through three expansion stages to the condenser, while the remainder of the steam is expanded through one ordinary and one multi-stage to the common exhaust.

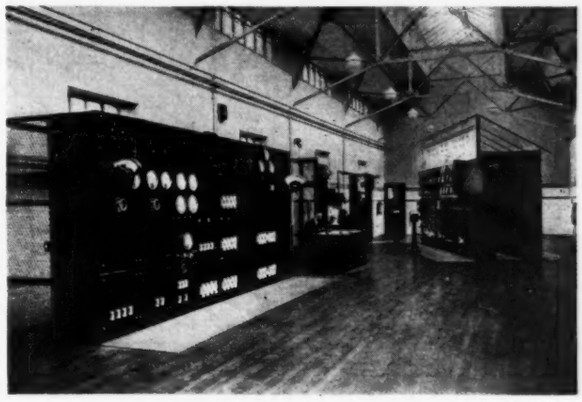
The condensers are of the Metro-Vick central flow type and installed 45 ft. below the turbines so as to reduce pumping losses to a minimum, being connected by mild steel trunking of 11 ft. dia., giving a very low pressure drop between the steam inlet and the ordinary pump suction.

Interesting also is the fact that the makeup water is supplied from evaporators operating on seawater, with steam diverted from the low-pressure stage of the turbine, the evaporators being of the horizontal straight tube type with tubes of solid drawn copper, while the extraction pump has special glands to prevent leakage of air into the system.

The cooling water is supplied from the River Severn by four culverts. The coal arrives either by water, using barges or ships, or by railway, and on the quay side are located two traveling cranes, each of 60 tons of coal per hour capacity, discharging into a receiving hopper operating in conjunction with a series of belt conveyors, which in turn deliver the coal to drag-link conveyors running from the bunkers above the boiler house.

The coal storage dump is of 100,000 sq. ft. area with a capacity of 20,000 tons, but designed for future extension to 45,000 tons. It is equipped with electrically-driven traveling jib cranes both for reclaiming and distributing the coal.

The ash handling plant is on the water-sluicing principle with two lines of troughs underneath the boiler house basement floor, each leading to a common ash sump, with final discharge of the quenched material to elevators leading to an over-



Control room.

head ferro-concrete ash bunker of 60 tons capacity, so that the material can be discharged direct into railway cars or loaded on to vehicles.

For the information and photographs used in this article, I wish to express my indebtedness to Mr. H. Faraday Proctor of the Bristol Corporation and Messrs. Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester.

Useful Charts for the Steam Plant Engineer

By B. J. Cross

The chart Fig. 1, has been prepared to permit a quick determination of the amount of coal required to produce a boiler horsepower and the equivalent evaporation per pound of fuel at different efficiencies. Equivalent evaporation or the evaporation "from and at 212 deg. fahr." is a unit of 970.2 B.t.u., the latent heat of evaporation at 212 deg. fahr.

A boiler horsepower, sometime in the dim past, has been arbitrarily set as 33,478 B.t.u. The terms

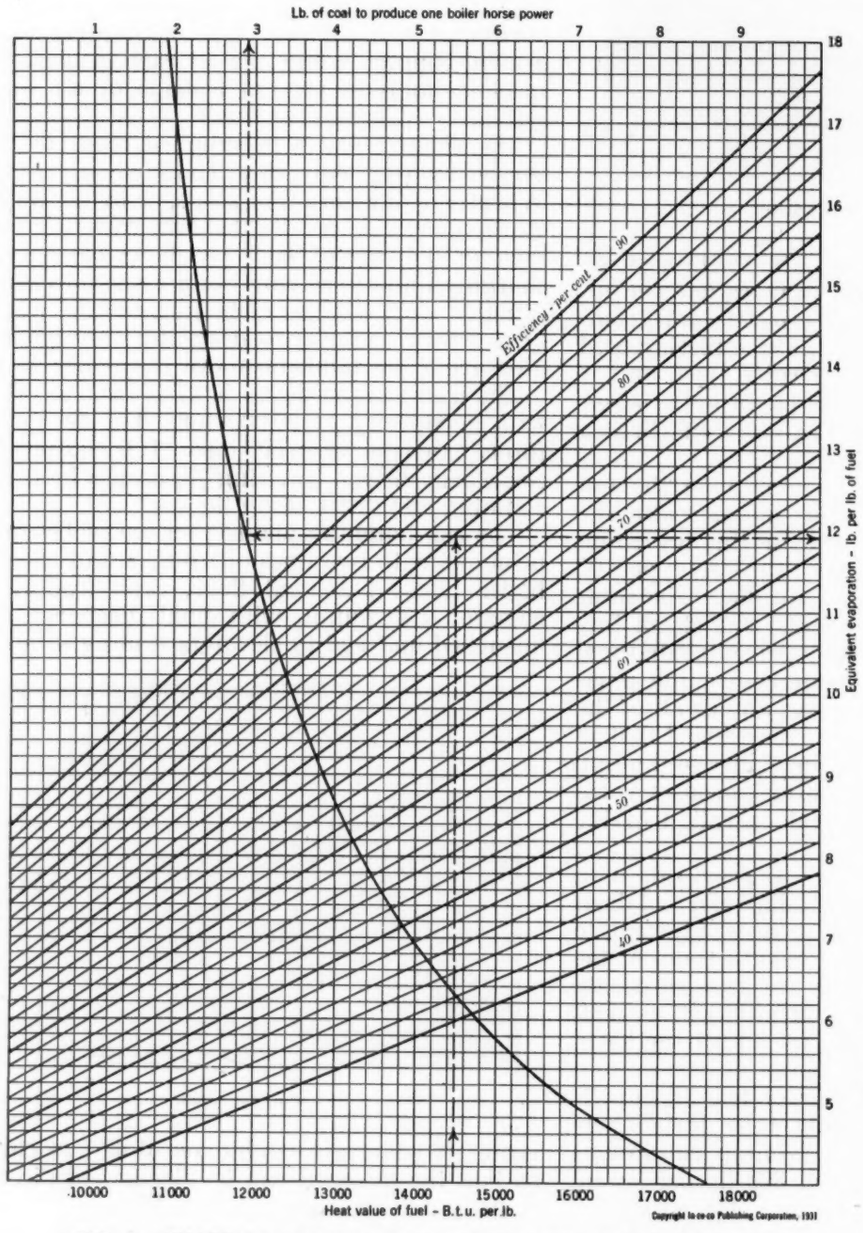


FIG. 1—CHART FOR DETERMINING EQUIVALENT EVAPORATION AND THE FUEL PER B.H.P. AT DIFFERENT EFFICIENCIES.

No. 25 of a series of charts for the graphical solution of steam plant problems.

"equivalent evaporation" and "factor of evaporation," which is the ratio of actual heat per lb. of steam to 970.2 B.t.u., are rapidly becoming obsolete and it appears that the term boiler horsepower is following them into discard. The more commonly used boiler surface unit is the square foot and the heat unit, 1000 B.t.u.

The value of the chart, Fig. 2, is due to the fact that coals from the same field have a fairly constant heat value when figured to a moisture- and ash-free basis. If a user of coal obtains his entire supply from one district, he may determine the heat value with a fair degree of accuracy from the percentage of moisture and ash, which is a comparatively simple analysis. Once the moisture- and ash-free heat value of a coal is determined by one or two reliable analyses, or from government reports, the heat value of any sample may be closely approximated by means of this chart.

No. 26 of a series of charts for the graphical solution of steam plant problems.

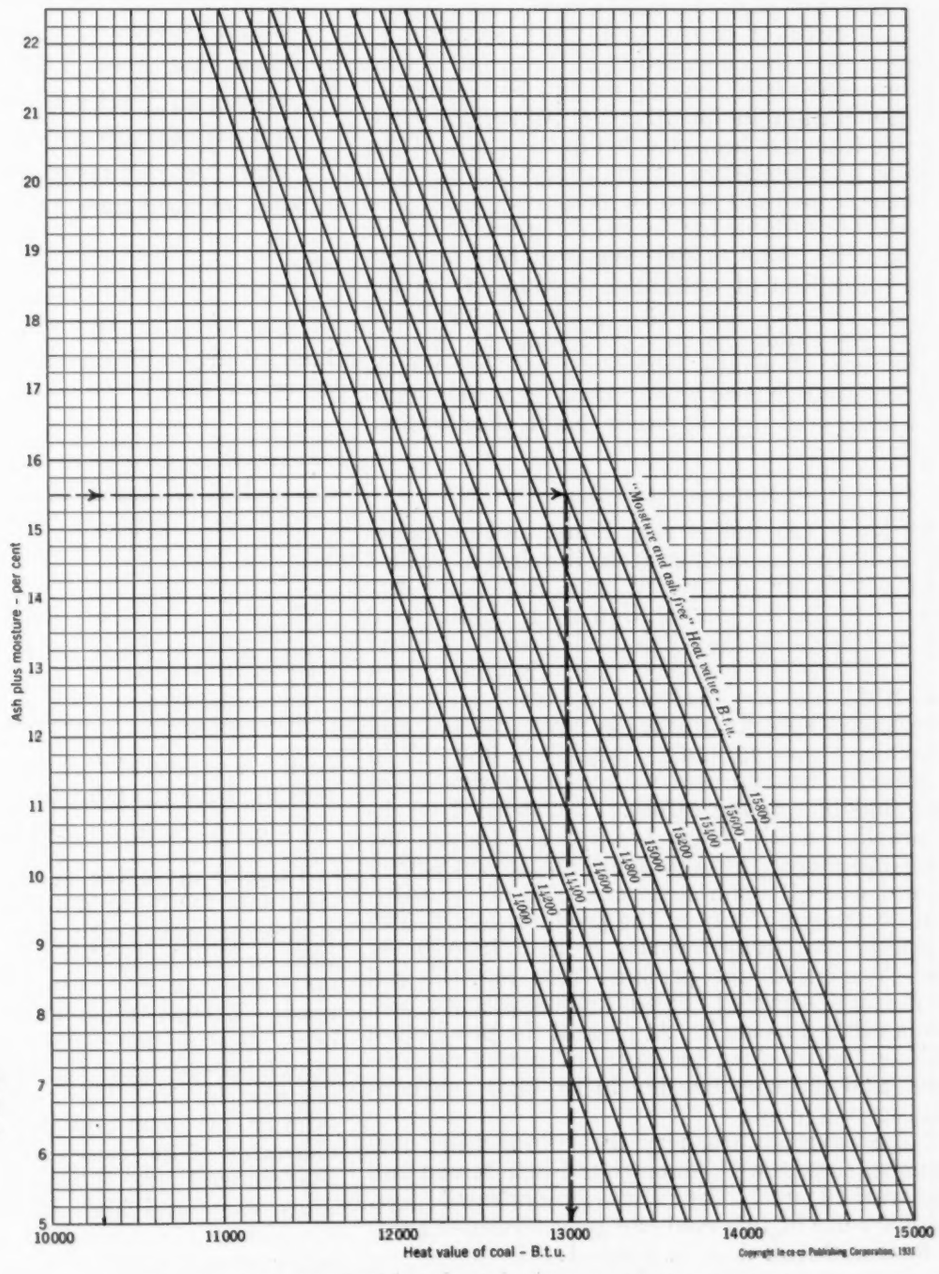


FIG. 2—CHART FOR DETERMINING THE HEAT VALUE OF COAL FROM MOISTURE AND ASH CONTENT.

Results of Re-Treatment Tests of Alabama Coals*

By
A. C. RICHARDSON
and B. W. GANDRUD

The authors describe and give the results of tests in which jig middlings from the Mary Lee bed at Sayreton, Alabama, were treated on a coal-washing table at the Bureau of Mines Laboratory, at Tuscaloosa. The results show that minus 3/16 inch middlings containing 21.5 per cent ash can be washed to 9.5 per cent ash with a recovery of 73.8 per cent. At this recovery the sulphur content was reduced from 1.00 to 0.74 per cent.

DURING the past two and a half years the U. S. Bureau of Mines and the University of Alabama, with the cooperation of the different coal operators, have been making an extensive study of coal preparation in the State of Alabama. Considerable time has been devoted to the study of the washing characteristics of the Mary Lee bed and the various methods used in preparing from it a low-ash coal suitable for the manufacture of metallurgical coke. One of the phases of this problem is the utilization of middlings products from the washing plants. This paper gives the results of treating jig middlings on a coal-washing table at the Bureau of Mines laboratory at Tuscaloosa, Ala. The sample used was secured from the Sayreton washery of the Republic Steel Corporation, Sayreton, Ala.

Washery Practice

The Mary Lee bed is very bony, and operators find it difficult to produce from this bed a washed coal much under 10 per cent ash. Experience has shown that in the preparation of a coking coal from the Mary Lee bed it is best to use a process which permits the recovery of a middlings product. Middlings are desirable because separation according to specific gravity is never perfect, and a middlings product makes possible a low ash in the primary washed coal without excessive losses of combustible in the refuse. The general washery practice on the Mary Lee bed is to crush the run-of-mine coal through some maximum screen size and wash it upon some one type of jig without re-treatment of any of the products made. The maximum size treated varies from 3 inch to ¾ inch. The middlings product from multiple-cell jigs is usually termed "boiler fuel" and when possible is utilized as such. At present the production of boiler fuel is often in excess of power requirements, and the surplus, due to its high ash content, becomes waste.

At the Sayreton washery the run-of-mine coal is crushed to pass a 1¼-inch round-hole screen and then washed upon four two-compartment jigs. The character of this coal can be determined from the float-and-sink data in Table 1.

The jigs at Sayreton produce washed coal, middlings, and refuse. The washed coal contains less than 10 per cent ash and is used for coke manufacture. The middlings are screened upon a ¾-inch square-mesh screen; the oversize is discarded as refuse and the undersize comprises the boiler fuel. A representative sample of this boiler fuel was used for the table test.

TABLE 1.—MARY LEE BED SAMPLED AT SAYRETON MINE. FLOAT-AND-SINK DATA OF RUN-OF-MINE COAL CRUSHED TO PASS A 1¼-INCH ROUND-HOLE SCREEN

Specific gravity	Weight, per cent	Ash,[1] per cent	Cumul. weight, per cent	Cumul. ash,[1] per cent
Float 1.28....	12.4	2.9	12.4	2.9
1.28—1.30....	17.5	5.4	29.9	4.4
1.30—1.38....	44.7	9.9	74.6	7.7
1.38—1.50....	10.1	18.9	84.7	9.0
1.50—1.70....	4.8	33.6	89.5	10.3
1.70—1.90....	2.9	49.7	92.4	11.6
1.90—2.20....	2.2	64.0	94.6	12.8
Sink 2.20....	5.4	81.7	100.0	16.5

[1] Moisture-free basis.

Screen-Sizing and Float-and-Sink Data

Table 2 gives the screen-sizing and float-and-sink data for the middlings. Column 1 shows the following screen-size distribution: Through ¾ inch on 3/16 inch, 25.0 per cent; through 3/16 inch on 14 mesh, 26.6 per cent; through 14 mesh on 300 mesh, 45.9 per cent; through 300 mesh, 2.5 per cent. It also shows that with the exception of the minus 300-mesh size the ash content decreases with decrease in size. Columns 4 to 7, inclusive, containing the float-and-sink data, show how the character of the coal varies in the different sizes. The coarsest size, ¾ inch to 3/16 inch, is exceedingly bony and high in ash. The float on 1.38 specific gravity was only 7.2 per cent by weight and analyzed 9.3 per cent ash. The other specific gravity fractions are so high in ash they must be rejected in the preparation of a coking coal. The 3/16-inch to 14 mesh and the 14-mesh to 300-mesh sizes contain a large proportion of clean coal. The

* Reprinted from U. S. Bureau of Mines Report of Investigations 3101.

fines through 300 mesh were not separated into specific gravity fractions for two reasons. First, the quantity is small; and in the second place, such fine material can only be improved by froth flotation, a process not to be considered at this time. Columns 8 and 9 show the distribution of sulphur in the specific-gravity fractions. These data show that the sulphur content varies with the ash content. Table 2 contains float-and-sink data for two composite samples, as follows: Through ¾ inch on 300 mesh and through 3/16 inch on 300 mesh. These two composites are given in order to show the effect of including and omitting the ¾ inch to 3/16 inch material in the sample to be retreated. The data are plotted in the form of washability curves in Figures 1 and 2.

The interpretation of the washability curves will not be discussed in this brief report. The reader who is not familiar with the method of constructing and interpreting these curves is referred to previous publications of the Bureau of Mines on washability studies of Alabama coals.

The ±0.10 specific gravity distribution curves indicate that a washed coal of 9.5 per cent ash should be obtainable with any standard type of equipment adapted to treatment of fine slack coal. This statement is based on the percentages of material within ±0.10 units specific gravity at the specific-gravity points where the separations should be made in order to obtain a washed coal of 9.5 per cent ash content. At 9.5 per cent cumulative ash the specific gravity distribution curves show only 16.0 per cent and 10.5 per cent, respectively, (Figs. 1 and 2) within this range, and these percentages are not high enough to make a washing problem particularly difficult.

Apparatus

The equipment available for this work was not adapted to the treatment of coal coarser than 3/16 inch; since the material above this size contained little of value, it was discarded, and only the minus 3/16 inch coal was washed. To have crushed the oversize would have increased the washing difficulty and decreased the table efficiency more than enough to offset the increased quantity of available low-ash coal.

The table used in this test had a quarter-size standard deck with modified riffling. The riffles were spaced at 1-inch centers. Every third riffle had a height of ½ inch at the head motion, and tapered uniformly toward the refuse end. The intermediate riffles were ⅛ inch high. High riffles increase the capacity and efficiency of a table by making it possible to maintain the depth of bed required for stratification. The table was equipped with swing sampling launders divided into 1-foot pockets, making it possible to separate the table discharge into zones 1 foot in length. Zones 1 to 8, inclusive, were on the coal discharge side of the deck and zones 9 to 11, inclusive, were on the refuse end.

Conduct of Test

Coal was fed to the table at the rate of 0.96 ton per hour. The variables such as slope, water, etc., were adjusted to give a good distribution of the bed over the surface of the deck, with approximately 25.0 per cent of the table discharge going over the refuse end. The adjustments were as follows: Length of stroke, 0.75 inch; number of strokes per minute, 240; cross slope, inches per foot, 0.5; elevation of refuse end above head motion end in inches, 3.75. When the table appeared to be working properly, zone samples of the entire table discharge were taken for a period of 45 seconds. Slimes from each sample were precipitated by means of a dilute ammonium sulphate solution,

TABLE 2.—SCREEN-SIZING AND FLOAT-AND-SINK DATA OF JIG MIDDLINGS SAMPLED AT SAYRETON 11-17-30

Description	Specific gravity	Weight, kilograms	Weight, per cent	Ash,[1] per cent	Cumul. weight, per cent	Cumul. ash,[1] per cent	Sulphur, per cent	Cumul. sulphur, per cent
Through ¾ inch on ⅜ inch. Head ash,[1] per cent, 50.2. Head sulphur, per cent, 1.33. Weight, kilograms, 20.6. Weight, per cent, 25.0.	Float on 1.38	1.44	7.2	9.3	7.2	9.3	0.76	0.76
	1.38—1.50	1.37	6.8	20.5	14.0	14.7	1.04	0.90
	1.50—1.70	4.29	21.3	35.9	35.3	27.5	1.34	1.16
	Sink in 1.70	13.00	64.7	62.7	100.0	50.3	1.46	1.36
		20.10						
Through ⅜ inch on 14 mesh. Head ash,[1] per cent, 31.0. Head sulphur, per cent, not determined. Weight, kilograms, 21.9. Weight, per cent, 26.6.	Float on 1.38	8.20	38.7	7.4	38.7	7.4	0.70	0.70
	1.38—1.50	3.13	14.8	19.5	53.5	10.7	0.85	0.74
	1.50—1.70	3.36	15.8	33.7	69.3	16.0	1.06	0.81
	Sink in 1.70	6.50	30.7	65.3	100.0	31.1	1.62	1.06
		21.19						
		Grams						
Through 14 mesh on 300 mesh. Head ash,[1] per cent, 15.8. Head sulphur, per cent, 0.98. Weight, kilograms, 37.9. Weight, per cent, 45.9.	Float on 1.38	69.46	76.1	5.5	76.1	5.5	0.69	0.69
	1.38—1.50	6.82	7.5	22.4	83.6	7.0	0.83	0.70
	1.50—1.70	4.94	5.4	35.0	89.0	8.7	1.04	0.72
	Sink in 1.70	10.05	11.0	72.7	100.0	15.8	3.00	0.97
		91.27						
Composite through ¾ inch on 300 mesh. Head ash, per cent, not determined. Head sulphur, per cent, not determined. Weight, kilograms, 80.4. Weight, per cent, 97.5.	Float on 1.38	....	48.2	6.1	48.2	6.1	0.70	0.70
	1.38—1.50	....	9.3	20.8	57.5	8.5	0.88	0.73
	1.50—1.70	....	12.3	34.9	69.8	13.1	1.18	0.81
	Sink in 1.70	....	30.2	65.1	100.0	28.8	1.77	1.10
Composite through ⅜ inch on 300 mesh. Head ash,[1] per cent, not determined. Head sulphur, per cent, not determined. Weight, kilograms, 59.8. Weight, per cent, 72.4.	Float on 1.38	....	62.4	5.9	62.4	5.9	0.69	0.69
	1.38—1.50	....	10.2	20.9	72.6	8.0	0.84	0.71
	1.50—1.70	....	9.2	34.2	81.8	11.0	1.05	0.75
	Sink in 1.70	....	18.2	68.1	100.0	21.4	2.15	1.00

[1] Moisture-free basis.

NOTE: The minus 300-mesh material weighed 2.1 kilograms and constituted 2.5 per cent of the total. It had an ash content of 18.5 per cent and a sulphur content of 0.95 per cent.

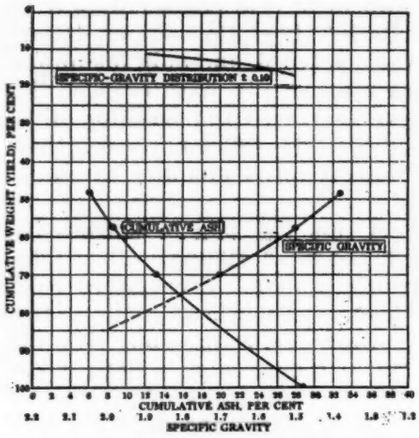


Fig. 1—Jig middlings through ¾ inch on 300 mesh.

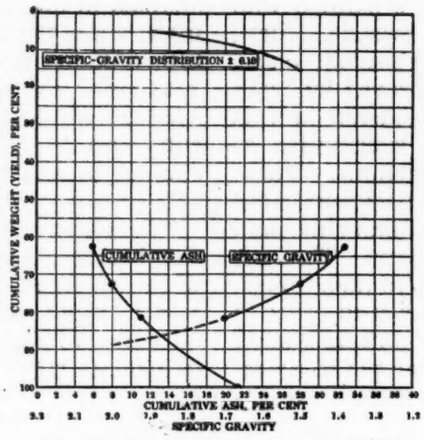


Fig. 2—Jig middlings through 3/16 inch on 300 mesh.

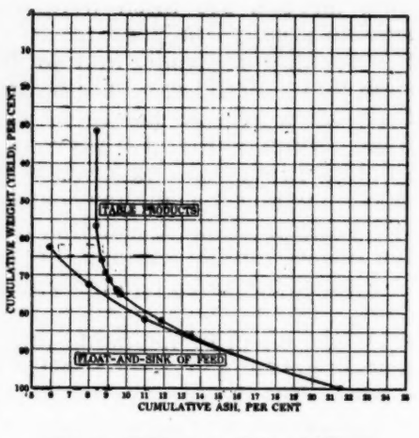


Fig. 3—Table test of jig middlings.

the water siphoned off, and the solids dried, weighed, and analyzed for moisture, ash, and sulphur.

Results of Table Test

The data from this test are given in Table 3. The first column gives the zones (numbered in sequence from the head motion) from which samples were taken.

TABLE 3.—TABLE TEST DATA

Zone	Weight, kilograms	Weight, per cent	Ash,[1] per cent	Cumul. weight, per cent	Cumul. ash,[1] per cent	Sulphur, per cent	Cumul. sulphur, per cent
1	3.45	31.5	8.4	31.5	8.4	0.73	0.73
2	2.77	25.3	8.5	56.8	8.4	0.72	0.73
3	1.00	9.2	10.1	66.0	8.7	0.78	0.73
4	0.36	3.3	12.8	69.3	8.9	0.80	0.74
5	0.21	1.9	16.1	71.2	9.1	0.85	0.74
6	0.28	2.6	20.5	73.8	9.5	0.84	0.74
7	0.07	0.7	22.8	74.5	9.6	0.96	0.74
8	0.07	0.6	25.9	75.1	9.7	0.95	0.74
9	0.77	7.0	34.8	82.1	11.9	1.08	0.77
10	0.44	4.0	46.3	86.1	13.5	1.16	0.79
11	1.52	13.9	71.6	100.0	21.5	2.25	1.00
	10.94						

[1] Moisture-free basis.

The headings of the remaining columns are self-explanatory. Columns 5 and 6, containing the cumulative weight per cent and cumulative ash per cent are plotted in Fig. 3 with the cumulative float-and-sink curve for the 3/16 inch to 300-mesh coal. From this chart it is possible to make a direct comparison between the float-and-sink results and the yield from the table test at various ash contents. Figures for such a comparison are given in Table 4.

TABLE 4.—COMPARISON OF FLOAT-AND-SINK YIELDS WITH TABLE TEST YIELDS

Ash, per cent	Float-and-sink [1] yield, per cent	Table test yield, per cent	Efficiency, per cent
8.0	72.6	0.0	0.0
8.5	74.2	61.0	82.2
9.0	76.0	70.0	92.1
9.5	77.5	73.8	95.2
10.0	79.0	76.2	96.5
21.5	100.0	100.0	100.0

[1] Float-and-sink data on minus ¾-inch to 300-mesh coal. Minus 300 mesh material equals 3.3 per cent of the sample and contains 18.5 per cent ash. The quantity of minus 300 mesh coal is small so that it may be considered similar to the ¾ inch to 300 mesh material without affecting the results.

It will be seen from these charts that the table shows no recovery below 8.5 per cent ash, but this is to be expected from the bony character of the feed. However, from 8.5 per cent ash to 10.0 per cent ash the table yield increases rapidly and the efficiency of operation increases proportionally.

The last two columns in Table 3 give the sulphur distribution in the zone products. The cumulative sulphur corresponding to a cumulative ash of 9.5 per cent is 0.74 per cent. Compared with 1.00 per cent, the sulphur analysis of the feed, this represents a sulphur reduction of 26.0 per cent.

Commercial Application

As a rule, one hesitates to give a commercial interpretation to laboratory results, for in laboratory work it is often possible by careful manipulation to obtain results that can not be equalled in larger-scale operations. This, however, is not true of the washing test under discussion. In order to obtain adequate stratification necessary to good separation upon a table, one must maintain a working bed of a certain minimum depth and the feed must be subjected to the action of the table for sufficient time to make the separation complete. These conditions are more easily secured and maintained upon commercial equipment. Experience has shown that a full-sized table normally gives higher operating efficiency than laboratory equipment. Furthermore, by modifying the riffling upon a standard table, a much larger range of sizes than can be handled upon a small deck may be treated.

Summary

The float-and-sink data show that the Sayreton middlings contain enough low-ash coal to warrant some type of re-treatment.

Practically all of the low ash coal is found in the material finer than 3/16 inch.

The 3/16-inch coal is ideally suited to treatment upon a coal-washing table.

The table test has shown that the minus 3/16-inch jig middlings containing 21.5 per cent ash can be washed to 9.5 per cent ash with a recovery of 73.8 per cent.

At the above recovery the sulphur content was reduced from 1.00 per cent to 0.74 per cent.

NEWS

Pertinent Items of Men and Affairs

World's Deepest Well Is Drilled

The No. 5-C well of the Big Lake Oil Company, a subsidiary of the Plymouth Oil Company, located on the University of Texas lands in Reagan County, Texas, has been drilled to a depth of 8,872 feet, where a new producing formation has been discovered one foot in sand, according to a recent announcement of the company.

This is the deepest producing oil well in the world, and it flows at the rate of 200 barrels of oil and 25,000 feet of gas an hour.

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E. O. Williams, associated for the past sixteen years with the transmission and industrial chain trade in various sales capacities, and formerly manager of the Howe Chain Company, has been placed in charge of the Philadelphia office of The Union Chain and Manufacturing Company, Bourse Building, Philadelphia.

•

Arthur W. Clark, former President of the Boston Oil Burner Association, has been appointed Managing Secretary of the newly created Dealer Division of the American Oil Burner Association, 342 Madison Avenue, New York.

•

The Ellison Draft Gage Company, Chicago, announces the appointment of the following exclusive representatives:

Hauer Equipment Company, Union Trust Building, Cincinnati, for the Cincinnati and Southwestern Ohio territory.

L. Wharton-Bickley, Bailey Building, Philadelphia, for the Eastern Pennsylvania and Southern New Jersey territory.

•

Anthracite Institute Elects General Disque

The Anthracite Institute has announced the selection of Gen. Brice P. Disque as executive director.

Resigning from the army in 1919, General Disque organized and directed the interests of the lumber industry of the Pacific Northwest and later became engaged in the financial and investment business in New York City.

The Anthracite Institute has a membership of all the major producers of anthracite coal in Pennsylvania, providing consumers with more than 50,000,000 tons of anthracite annually.

Oil Burner Convention to be held in Boston

The ninth annual convention and oil burner show of the American Oil Burner Association will be held in Boston in April, 1932, it was decided at a recent meeting of the Board of Directors. It was also decided to provide for "live" exhibits, or burners in actual operation in the show.

The convention, which is expected to attract over 3,000 out-of-town visitors, has never been held in New England and the selection of Boston for 1932 is in line with the policy of the association to hold its annual convention in a different city each year.

•

R. D. Bean, formerly Manager of the Engineering Development Department of The Brown Instrument Company, Philadelphia, has been made Chief Engineer of that company.

•

The Armstrong Cork Company, Lancaster, Pennsylvania, announces that all of its Cincinnati branch sales offices and warehouses have been consolidated at 232 West Seventh Street, Cincinnati. The move, which brings together sales divisions that have previously maintained separate offices, was completed July 20.

•

Henry L. Doherty, president of Cities Service Company and head of Henry L. Doherty & Company, was honored recently by Lehigh University with the honorary degree of Doctor of Engineering, given "in recognition of his distinguished contributions to the arts and sciences of gas, electric and petroleum production, distribution and utilization." This is the third honorary degree to be conferred on Mr. Doherty.

•

Texas-Chicago Gas Line Nearing Completion

Natural gas will be flowing all the way from the Texas Panhandle into Chicago shortly if present plans of the Natural Gas Company of America, which will operate the line, are carried out on schedule. The 24-in. pipe line will be 950 miles long and is being constructed by the Continental Construction Company. It will serve domestic and industrial markets in Chicago and many cities and towns in Texas, Oklahoma, Missouri, Kansas and Iowa.

This line will be 1250 miles long and is being constructed by the Panhandle Eastern Pipe Line Company to points in Missouri, Illinois, Indiana, and other states. When completed it will have a carrying capacity of 130,000,000 cu. ft. of gas daily, and will serve about 75 cities and towns. Both of these big interstate gas pipe lines pass through the Panhandle section of Oklahoma.

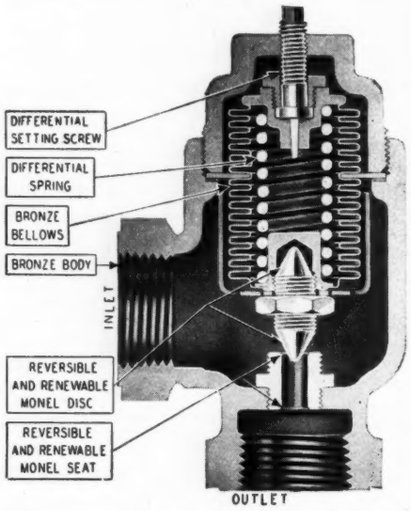
NEW EQUIPMENT

of interest to steam plant Engineers

New Steam Trap

The C. J. Tagliabue Manufacturing Company, Brooklyn, N. Y., manufacturers of recording and controlling instruments is now offering to industrial users a new and unique steam trap.

There are several outstanding features of this new steam trap that emphasize its economy in operation. The new and exclusive Differential Setting Feature makes



it possible for the TAG Steam Trap to discharge condensate at a temperature corresponding to a uniform differential pressure from 0 to 20 lb. below the operating steam pressure. If the trap is set to discharge condensate at a temperature corresponding to as much as 20 lb. less than the operating steam pressure, it will discharge the condensate at this differential regardless of whether the steam pressure is 50 lb., 75 lb., or 125 lb., and without any further adjustment of the Differential Setting.

There are other advantages including reversible and renewable Monel seats and discs. Simply by unscrewing and reversing the seat the outlet end becomes a new seat. Merely by inverting the disc, the reverse, extra disc is brought into play.

The body and bellows are of bronze.

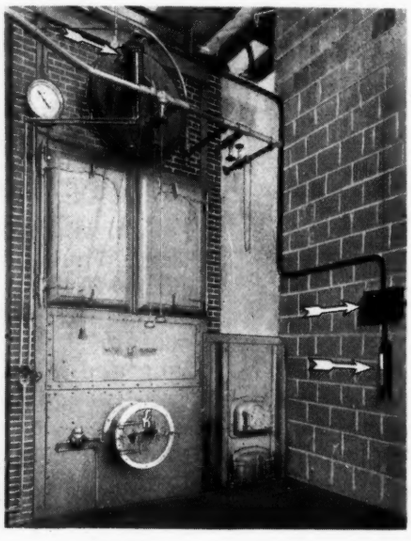
The Tagliabue Company has concentrated on only one size—the 1 inch, as the full 5/16 in. valve opening assures ample capacity and permits of easy interchangeability on every steam line. Thus only one set of replacement parts is required for any application within the capacity of the TAG Trap.

Boiler Water Level Indicator

The S. & K. Televisor shown in the accompanying illustration, is a boiler water level indicator recently put on the market by the Schutte and Koerting Company, Philadelphia. The outstanding feature of this appliance is the fact that it operates electrically, the indicator being located some distance from boiler drum. The Televisor consists of three separate units: the transmitter which is attached to boiler drum and takes the place of, or is used in conjunction with, the standard water column; the distributor which is installed on a near-by wall, and the indicator which is located at convenient height either on the boiler room wall or elsewhere in the plant. The transmitter contains a set of electrodes of unequal length and is provided with connections for standard gauge glass, try cocks and blow-down. The electrodes are connected by cable to a set of relays in the distributor and make contact with boiler water as the level rises in transmitter.

The indicator contains no liquids, but is fitted with a double row of small lamps that illuminate a vertical prism. These lamps receive current through the relays in the distributor. The electrodes in contact with the water light green lamps in the indicator while those electrodes above water level light red lamps, the two sets showing in the prism as a column of light, the lower section of which is green, the upper section red. The dividing line between the colors is the water level reading with reference to predetermined low and high limits. The use of double pole relays and a double set of lights makes the operation trouble proof. Additional indicators may be installed in the control room or in any other section of the power house where boiler water level readings are desired. These indicators can be equipped with bell alarm for low and high water levels.

The complete system operates from ordinary light circuit, a transformer in



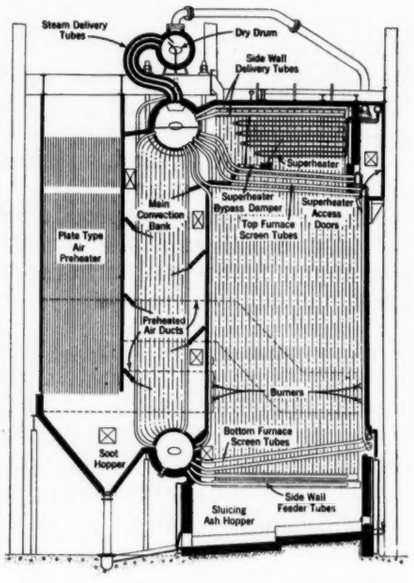
the distributor being used to step the current down to low voltage. The current consumption does not exceed 40 watts.

The S. & K. Televisor is particularly recommended for high set boilers or for any installation where it is difficult to read the ordinary water gage glass. They are built for pressures up to 1800 lb.

Combustion Steam Generator

Combustion Engineering Corporation, 200 Madison Avenue, New York, is now offering the Combustion Steam Generator, a standard steam generating unit built in various sizes and providing a wide range of capacities at any desired conditions of steam temperature and pressure. Detail designs have been completed for eight sizes with capacities ranging from 70,000 to 400,000 lb. of steam per hour.

As shown in the accompanying illustration, this design combines in one unit all



the elements required for fuel-burning, steam generation and superheating, heat recovery and ash disposal. There are no novel or radical departures from fundamentals, but rather the design represents a highly compact and simple arrangement of long and well-established elements.

All four walls of the furnace are water-cooled, each wall being composed of a solid row of tubes with only sufficient space between them for construction requirements. The water-wall feeder and delivery tubes, at the bottom and top of the furnace respectively, complete the heating surface of the furnace proper nearly all of which is exposed to radiant as well as convection heat.

The result of this arrangement of wall tubes and circulators is a furnace built completely of water tubes to the exclusion of exposed refractories and having the maximum attainable quantity of contained water with provision for the highest possible freedom of circulation.

This type of furnace is perfectly adapted to the type of firing used, i.e.,—the corner-tangential system which produces intense turbulence with extreme rapidity of combustion and correspondingly high temperatures,—these high temperatures being the result (not the cause) of the high rates of combustion.

Another feature of interest is the superheater by-pass damper which affords a unique and much needed means of controlling superheat temperature. Adequate space is provided for the superheater which is so located in the assembly as to permit of simple supports and a degree of accessibility that is unusual in boiler design and construction.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

A Monograph of Viscometry

By Guy Barr

RELATIVELY little has been published in book form on the subject of measurement of the viscosity of liquids (resistance of a fluid to the relative motion of its particles,—internal friction). This book deals with the subject in a comprehensive and scholarly manner. The author, who is Senior Assistant of the National Physical Laboratory, Teddington, England, evidences a deep familiarity with the literature of the subject and his frequent footnotes are in themselves a valuable bibliography.

In the past, the practical determination of viscosity has been more or less a matter of skilled observation involving the use of definite but not particularly accurate or scientific methods. The author of this book describes most of the more scientific methods that have been developed and discusses the theoretical and practical difficulties that affect each of them. He has not dealt with the viscosity of solids because of the extent of the subject and because most of the methods of measurement are unlike those available for liquids or gases.

The following list of chapter headings indicate the nature and scope of this treatment: Introductory and Historical Notes; The Viscous Flow of Fluids in Tubes; Tube Viscometers for Absolute Measurements; Commercial Absolute Viscometers; Capillary Viscometers for Relative Measurements; Flow Between Parallel Planes; The Transpiration of Gases; The Falling-Sphere Method; Rotational and Oscillational Viscometers; Miscellaneous Methods of Viscometry; The Study of Anomalous Systems.

This book is 6¾ by 10 overall and contains 320 pages. The price is $12.00.

Modern Combustion, Coal Economics and Fuel Fallacies

By C. V. Beck

THIS book is written by a coal man who typifies the new viewpoint of the coal industry, namely, that coal must be sold on its merit in competition with other fuels, that the industry must cooperate with coal users in the selection of the proper coal for their conditions, that the preparation of coal for specific uses must be undertaken on a much larger scale than heretofore, and that the future of the coal industry depends largely upon its skill in merchandising as well as in producing its product.

Mr. Beck writes interestingly on all phases of coal, its production, preparation and utilization. He has devoted chapters to modern combustion viewed both from theoretical and practical angles and has included much information and data that will be of interest to operating engineers as well as executives.

The following titles of chapters in this section of the book indicate the general character of the treatment: Elementary Combustion; Efficient Combustion; Excess Air and Attainable Temperatures; Sulphur and Coal Storage; Chemistry and Coal Applications; Smoke; Smokeless Furnaces; Smoke Reduction Gadgets; Furnace Design; Furnace Volume; Resume of Combustion; Definite Chemical Reactions of Combustion.

One of the marked features of the book is its readability. The layman who has an interest in coal and its use will find it as informative as will the engineer immediately concerned with the subject.

Considerable space is devoted to small stokers and to comparisons of the economic value of different fuels.

This book is 7¼ by 10½ overall and contains 380 pages. The price is $3.00.

Diesel Engine Operation, Maintenance and Repair

By Charles H. Bushnell

THE first chapters of this book are devoted to internal combustion engine cycles, thermodynamics, combustion and fuel. The next two chapters cover vaporizing, bixing and ignition systems, and mechanical fuel injection. The succeeding chapters are devoted to the principal parts and elements of Diesel engines, and to such subjects as engine nomenclature and rating, lubrication, knocks, and operation and maintenance. The Appendix entitled "Conversion Tables and Equivalents" contains reference tables and other valuable data.

The author points out in the preface that the book is written from the viewpoint of the operating engineer and that the intent has been to treat the fundamental principles rather than the details of design which are constantly changing.

This book is 6¼ by 9¼ overall and contains 285 pages. The price is $3.50.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Control System Fittings

The installation of a System of Automatic Combustion Control requires certain mechanical connections between the Regulating Units of the System and the devices which are to be controlled such as dampers, motor controllers, regulating valves, shafts, etc. The Carrick Stiff-Arm Fittings illustrated and described in a new bulletin have been designed and are manufactured by the Carrick Engineering Company especiallv for the purpose of providing means for rigidly connecting the controlled devices to the Regulating Units. The use of these special fittings will be found advantageous in securing positive operation of the devices to be controlled, simplifying erection and reducing the installation cost of a Control System. 4 pages, 8½ x 11—Carrick Engineering Company, 431 So. Dearborn Street, Chicago.

Flow and Pressure Regulators

New catalog No. 4 presents Mercon Regulators. Although built on the same general principle these regulators are applicable to the control of feedwater excess pressure, constant reduced pressure, constant back pressure, constant differential and constant flow. The catalog is well illustrated with construction details and application arrangements. 24 pages and cover, 8½ x 11—The Mercon Regulator Company, One LaSalle Street, Chicago.

Indicating Temperature Controller

A new bulletin has been issued describing and illustrating the Brown Indicating Temperature Controller recently introduced for automatically controlling relatively high temperature processes and units such as heat treating furnaces, enameling furnaces, oil stills and towers, brick and pottery kilns, glass furnaces, galvanizing tanks, etc. This controller has mercury switches, with enclosed contacts and is ruggedly built for rough service. 12 page broadside, 8½ x 11—The Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia.

Liquid Flow Meters

Foxboro Liquid Flow Meters are described in bulletin No. 173, just issued. The theory of flow measurement and the operation, design, construction and application of instruments used to measure liquid flow are clearly described in this new booklet. The illustrations are particularly well chosen and considerable engineering information on metering is included. 40 pages and cover, 8½ x 11—The Foxboro Company, Foxboro, Mass.

Oil Burners

Peabody Oil Burners and auxiliary oil burning equipment are described in new bulletin No. 106. The wide range of burner designs and application arrangements are shown. The illustrations are particularly clear and show the details of construction and suggested methods of application. Photographs of existing installations are supplemented by line drawings showing cross sections through the boiler and furnaces. 32 pages and cover, 8½ x 11—Peabody Engineering Corporation, 40 East 41st Street, New York.

Semi-Portable Boilers

A new bulletin describes the H-W-W Premier Semi-Portable Boiler, one of the most popular types for small and medium size power plants for a great many years. It is primarily a power boiler but is also used for heating purposes. Standard pressures in which it is made are 100, 125 and 150 lb., and when required it is made for higher pressures. The Premier Boiler is superior to the usual firebox heating boiler; its rugged design contributes to its longer life; it has no water legs to form mud pockets and cause burning of firebox plate; its refractory-lined furnace insures high capacity and good combustion. The design and construction of the boiler conform to the requirements of the A.S.M.E. Boiler Code. 8 pages, 8½ x 11—The Hedges-Walsh-Weidner Company, Chattanooga, Tenn.

Steam Generating Equipment

"Fuel Burning and Steam Generating Equipment" is the title of a general condensed catalog recently issued to present Combustion Engineering apparatus which is particularly applicable to the small and medium size industrial plant. Boilers, stokers, pulverized fuel systems and air preheaters are briefly described. The illustrations show a wide range of application schemes. 10 pages and cover, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Steam Piping

Bulletin No. 106, recently issued, describes the use of Tube-Turns in the fabrication of steam piping. A useful chart, reproduced as a blue print, is presented to facilitate the rapid and accurate calculation of expansion loops made up with Tube-Turns and straight lengths of pipe. 4 pages, 8½ x 11—Tube Turns, Inc., 1303 South Shelby Street, Louisville, Ky.

Turbo Blowers

Bulletin No. 3132, just issued, illustrates and describes the Ingersoll-Rand line of turbo-blowers and turbo-compressors. The bulletin covers the construction and operation of single-stage and multi-stage blowers for discharge pressures of one to 40 pounds and capacities of 3,000 to 100,000 cubic feet per minute; and turbo-compressors for discharge pressures up to 110 pounds and capacities of 8,000 to 10,000 cubic feet per minute. The booklet contains 37 illustrations, including sectional drawings, charts, blower parts, and complete units. 44 pages and cover, 8½ x 11—Ingersoll-Rand Company, 11 Broadway, New York.

Vertical Steam Engines

Wachs fully enclosed, self-oiling, vertical steam engines are described in bulletin R-31. These engines are particularly applicable to driving any steam power plant equipment such as mechanical stokers, forced and induced draft fans and centrifugal type pumps. Specifications for five sizes are included together with dimension sheets and horsepower rating tables. The illustrations show details of construction and various application arrangements. 12 pages. 8½ x 11—The E. H. Wachs Company, 1535 Dayton Street, Chicago.

Water Level Indicator

New bulletin No. 15A presents the Schutte and Koerting Water Level Televisor, a new electrical instrument for indicating water levels in boilers or tanks at one or more distant points. The Indicator contains no liquid but consists of a glass prism behind which is an ingenious arrangement of small electric lamps so arranged that the upper portion of the prism shows red and the lower portion green. The dividing line between the two colors indicates the height of the water level. The system may be equipped with an alarm bell for signaling high and low water level. Colored charts show the details of construction and various application arrangements. 8 pages. 8½ x 11—Schutte and Koerting Company, Philadelphia.

Waterproof Sealing Compound

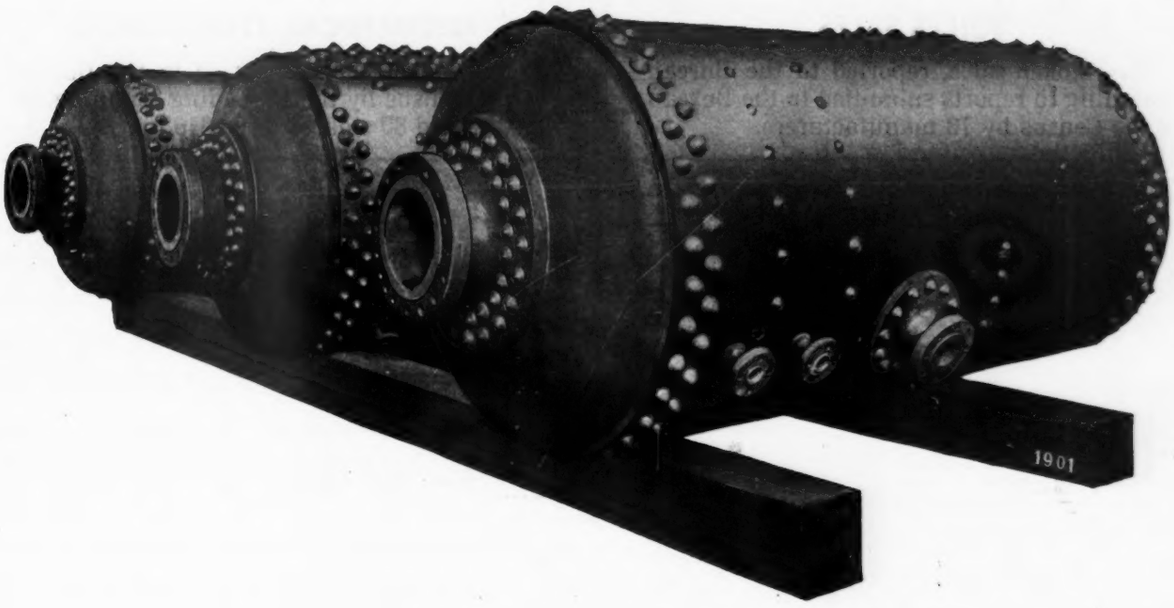
Hydro-Seal, a waterproof sealing compound for water, gas and air lines is described in a new bulletin. Hydro-Seal may be used with thread, flange and gasket joints. Due to the lubricating properties of the ingredients this material assists in making up thread joints and the rust preventing and protective qualities make "frozen joints" impossible. 8 pages, 3½ x 6⅜—Quigley Company, 56 West 45th Street, New York.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York



"HATS OFF TO THE COCHRANE STEAM PURIFIER"

writes the Plant Engineer of a concern which installed Cochrane Steam Purifiers to protect two Uniflow engines. The three H.R.T. boilers are fed with water containing a large amount of dissolved solids, resulting in severe priming. On one occasion when a sudden load was thrown on the engines, the level in the gage glasses dropped precipitately six inches (representing 4000 to 6000 lbs. of water) and the operating men's hearts lost a few beats while they waited to see whether or not slugs of water would reach the engines with the steam. However, the engines continued to run smoothly, because during this time, the Cochrane Dischargers draining the Purifiers were discharging "for fair."

In regular operation, Cochrane Purifiers deliver clean, dry steam regardless of boiler load or of concentration of boiler water. They never require cleaning, permit free flow of steam and last longer than the boiler itself.

Ask for Bulletin C-684

COCHRANE CORPORATION

3160 North 17th Street, Philadelphia, Pa.

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

May stoker sales, reported to the Bureau according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	646	572,681
Total (5 mo.)	5,092	5,684,205	3,079	3,261,734
June	1,360	1,588,553		
July	1,309	1,410,096		
August	1,371	1,356,751		
September	1,254	1,282,388		
October	1,189	851,525		
November	777	709,322		
December	814	587,053		
Total (Year)	13,166	13,469,893		

TOTALS FOR FIRST 5 MONTHS AND NEW ORDERS, BY KIND, PLACED IN MAY, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	May, 1930 No.	May, 1930 Sq. ft.	May, 1931 No.	May, 1931 Sq. ft.
Stationary:								
Total	4,993	5,315,160	2,977	2,892,367	1,262	1,246,901	630	525,942
Water tube	471	2,594,334	272	1,318,992	98	530,902	46	196,628
Horizontal return tubular	375	522,346	198	240,319	95	131,575	44	55,675
Vertical fire tube	553	173,910	275	75,758	130	40,589	44	15,865
Locomotive not railway	91	70,640	48	45,745	15	13,136	9	4,312
Steel heating [1]	2,773	1,253,189	1,820	877,998	728	327,763	416	188,075
Oil country	432	494,346	215	240,396	120	141,159	38	44,019
Self contained portable [2]	224	157,523	121	75,467	56	39,982	26	18,259
Miscellaneous	74	48,872	28	17,692	20	21,795	7	3,109

[1] As differentiated from power.
[2] Not including types listed above.

MECHANICAL STOKER SALES

May stoker sales, reported to the Bureau of the Census by the 11 leading manufacturers, totaled 80 stokers of 23,646 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929						
Total (First 5 mo.)	609	225,899	209	32,596	400	193,303
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
Total (5 mo.)	419	136,108	182	25,419	237	110,689
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
Total (5 mo.)	360	100,513	165	26,087	195	74,426

PULVERIZED FUEL EQUIPMENT SALES

May orders for coal pulverizers as reported to the Bureau of the Census aggregated 3 pulverizers having a total capacity of 3,800 lb.

Year and Month	STORAGE SYSTEM: PULVERIZERS: Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr.: For contract	Based on New River coal, 3% moist	BOILERS: Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS								
1931								
January	2	2	..	60,000	88,000	1	51,177	704,000
February	1	..	1	40,000	50,000	1	29,100	375,000
March	2	2	..	60,000	60,000	..	.....	.....
April	2	2	..	60,000	88,000	1	34,300	592,000
May	..	..	..	....	....	..	....	.....
Total (5 mo.)	7	6	1	220,000	286,000	3	114,577	1,671,000
FOR INSTALLATION UNDER FIRE-TUBE BOILERS								
1931								
January	..	..	..	.....	.....	..	.....	.....
February	..	..	..	.....	.....	..	.....	.....
March	..	..	..	.....	.....	..	.....	.....
April	..	..	..	.....	.....	..	.....	.....
May	..	..	..	....	....	..	....	.....
Total (5 mo.)	..	..	..	....	....	..	....	....

Year and Month	DIRECT FIRED OR UNIT SYSTEM: PULVERIZERS: Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr.: For contract	Based on New River coal, 3% moist	BOILERS: Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS								
1931								
January	8	4	4	40,500	55,300	9	42,970	412,675
February	2	2	..	8,000	8,500	1	7,570	75,000
March	13	13	..	122,000	143,000	8	93,960	1,404,000
April	9	8	1	49,250	53,700	6	46,300	538,200
May	..	..	..	....	....	..	....	.....
Total (5 mo.)	32	27	5	219,750	260,500	24	190,800	2,429,875
FOR INSTALLATION UNDER FIRE-TUBE BOILERS								
1931								
January	6	..	6	6.000	6,750	6	7,500	53,350
February	3	..	3	2,250	2,250	3	3,000	22.350
March	2	1	1	2,750	2,750	1	3,004	22,500
April	1	..	1	4,000	4,250	2	6,700	45,000
May	3	1	2	3,800	4,000	3	6,000	27,000
Total (5 mo.)	15	2	13	18,800	20,000	15	26,204	170,200

The Dry Quenching of Coke is an Economic Necessity

THE dry quenching of coke eliminates the wasteful and destructive method of quenching coke by deluging it with water, which is always accompanied by clouds of dust-laden vapors, destructive of plant life and steel work, to say nothing of the comfort and health of plant personnel.

In the Sulzer system of Dry Quenching, the cooling of the hot coke to a temperature suitable for handling, screening, storing and shipping is accomplished by circulating (automatically formed) inert gases in a closed cycle, first through the mass of hot coke where the gases extract the sensible heat, then through a steam boiler, where the hot gases transfer the heat to the water in the boiler circulation and convert it into steam.

Reports show outputs of 940 lb. of steam to over 1000 lb. of steam per net ton of coke cooled. This steam is secured from heat that formerly was entirely wasted.

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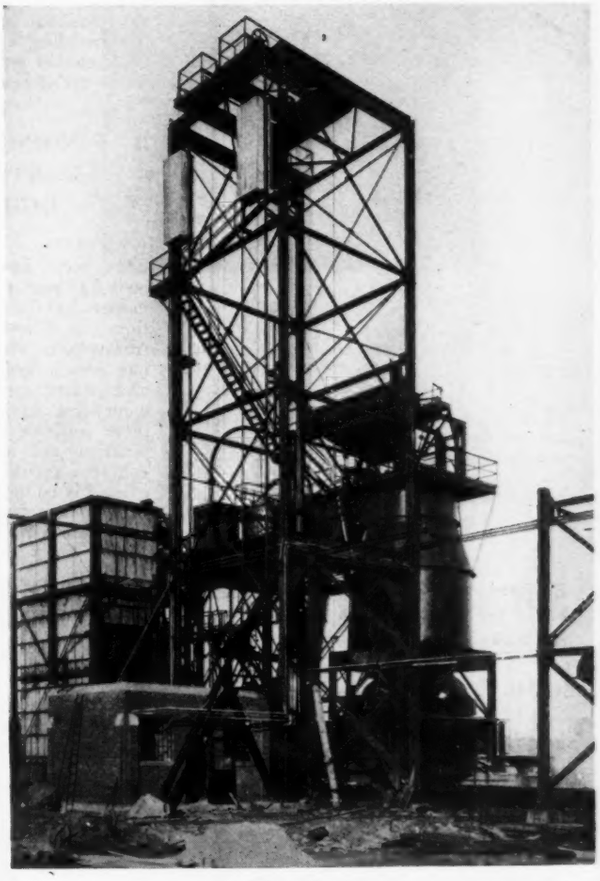
Reprint of a paper recently delivered on the Dry Quenching of Coke is available. May we send you a copy?



Dry Quenching Installation at Consumers Power Company's plant, Flint, Michigan.

DRY QUENCHING EQUIPMENT CORPORATION
200 MADISON AVENUE NEW YORK

Practical BOOKS for the ENGINEER

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200 Madison Ave. New York

Books No.....

Postage prepaid in the United States on all orders accompanied by remittance or amounting to five dollars or over.

1 ELEMENTS OF THERMODYNAMICS

by Ernest M. Fernald, M. M. E.

330 Pages Price $3.50

The author endeavors to impart an adequate and flexible technique for quantitative dealing with various situations, together with data sufficient for the simpler ones. Also, clear ideas as to the limitations of engineering practice of universal laws, and as to the condition which must be met before current practice can approach the ultimate.

The properties, processes and cycles, of steam and perfect gases are treated fully. Twenty-three pages are devoted to the flow of these substances.

Other topics treated are refrigeration, evaporation, compressed air.

The amount of space devoted to available energy and the manner of reaching conclusions, reflect a desire to render this topic better understood than it seems usually to be.

The book embodies the more valid results of a thinking-through of the subject by the author after a number of years away from its theoretical aspects.

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Steam Pressure Reduction With Control of Superheat

(Continued from page 22)

adequate supply of steam at all times and during these periods of shortage the additional low pressure steam is made up from the low pressure boilers which are equipped with automatic combustion control which increases their rate of operation to meet this additional demand for steam.

Fig. 3 shows the temperatures entering and leaving the de-superheater.

A somewhat different condition exists in plants generating large amounts of steam from waste heat or by-product fuel. In such cases it is desirable to generate all the steam that can be made with the fuel available, and to unload the excess to the low pressure system. The high pressure master controller, therefore, controls a valve which acts as an unloader but periods may occur when unloading the excess may run the pressure in the low pressure system above the desired amount. If this occurs the low pressure master takes control of the operation of the reducing valve and only permits as much steam to enter the low pressure system as is required to maintain the pressure. The excess steam must then be taken care of on the high pressure side by reducing the amount of by-product fuel or waste heat going to the boilers, which can be done automatically if desired.

The same equipment is required whether the reducing valve acts primarily as an unloader or a pressure reducing valve and the system can be changed to operate in one manner or another by a simple adjustment.

•

Handling Coal and Ashes at Longworth Steam Station

(Continued from page 38)

push-button semi-automatic type, so that all the ash man has to do is to discharge his load and push a button. The skip car automatically elevates, discharges, returns and comes to rest until the button is pushed again.

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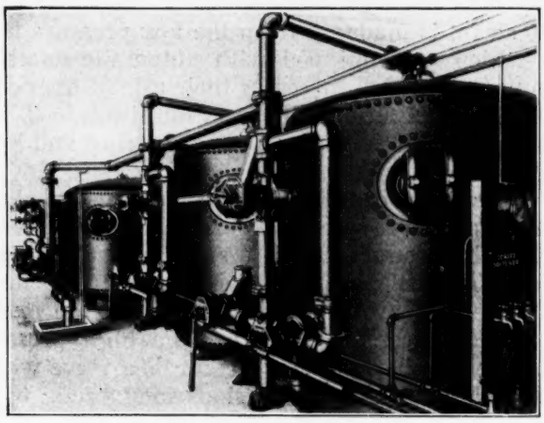

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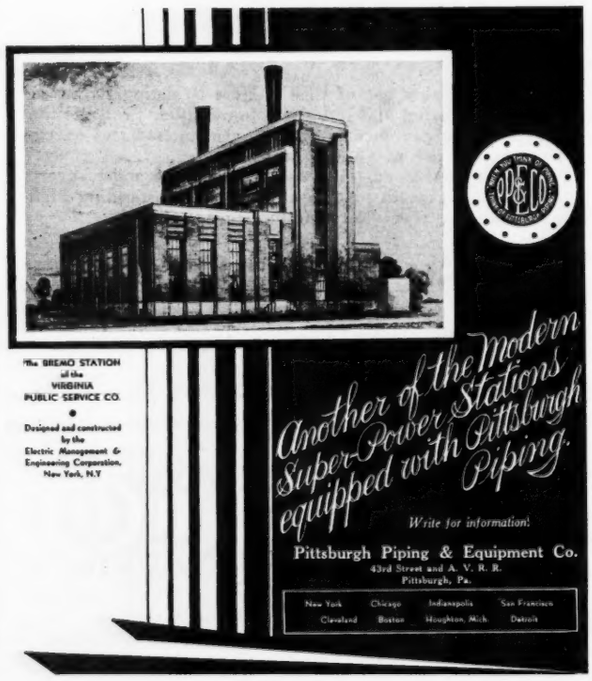
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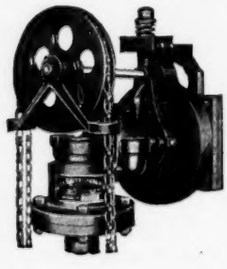

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